SYSTEM BUILDING FOR SOCIOTECHNICAL CHANGE:

A SOCIOLOGICAL ANALYSIS OF THE EFFORTS OF ENERGY-EFFICIENCY ADVOCATES IN

THE U.S. RESIDENTIAL HOUSING SYSTEM

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A dissertation submitted for the partial fulfillment of
requirements for the degree of a

DOCTORATE OF PHILOSOPHY

WASHINGTON STATE UNIVERSITY
Department of Sociology

August 2006

To the Faculty of Washington State University:

The members of the committee appointed to examine the dissertation of Bryan E. Burke find it satisfactory and recommend it be accepted

Chair

Acknowledgements

I would like to thank the intellectual mentoring that I have received from my chair Dr. Loren Lutzenhiser for over a decade now, and the demanding but always supportive guidance of Dr. David Sonnenfeld during the writing process. I also appreciate the assistance that committee members Dr. Raymond Jussaume and Dr. Louis Gray have provided, and graduate student coordinator Dr. Lisa McIntyre. Field research would not have been possible without funding from the Department of Sociology and the Graduate College of Washington State University. My time in the field would not have been nearly as enjoyable if not for all the kind souls on the road who offered me a place to sleep, a meal, or a ride to the bus station.

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Abstract

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Alternative technology advocates lack effective hands-on theories of technological change. This study presents a new, sociological, organization-based theory of system building and also provides the results of empirical, field-based research of efforts to encourage energy efficiency in the United States' residential housing industry from the early 1980s to 2005. Advocates can facilitate technological change by being situated within dominant economic institutions and having a full set of organizational capacities for system building, instead of merely politically advocating from the periphery of an industry. Technological change occurs when organizations shape sociotechnical systems of institutions, organizations, culture, and technologies to support certain technologies over others. Organizations are successful at this when they have the capacity to collect information, control, coordinate, flexibly finance, and strategically plan system building. This capacity is used to invent new technologies, new organizational routines and institutions, and then integrate all of these parts into the sociotechnical systems to support certain technologies. Further theory is inductively developed through reviewing the success that historical corporations have attained at system building. For corporations, organizational capacities have manifested as strategic central offices, multiple divisions, R&D units, and marketing departments allowing corporations to facilitate fast-paced, highly dynamic technological change. The thesis that *advocates of alternative technology have lacked the organizational capacities for effective system building* is evaluated through a case study of Home Energy Ratings System (HERS) and Energy

Efficient Mortgages (EEMs). Research findings mostly support this thesis, and caveats are stated. Additional sociological theory is offered about networks of small organizations engaging in system building. Also, large, complex, centralized organizations and/or other large structures are crucial for shaping system-wide transformations. However, size is probably not the only factor, and small organizations can play a role. Policy recommendations assume that the same or analogous organizational structures used by corporations for system building can also be used by other types of organizations for system building, such as by progressive advocates of alternative technology.

KEY WORDS: sociotechnical change, sociotechnical systems, social organizations, theory, environment, alternative technology, market instruments, residential housing, energy efficiency, home energy rating system, energy efficient mortgages.

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List of Acronyms

CHEERS	California Home Energy Efficiency Rating System
DOE	U.S. Department of Energy
DSM	Demand Side Management program
EEM	Energy Efficient Mortgage
EERE	Office Energy Efficiency and Renewable Energy, Department of Energy
EPA	Environmental Protection Agency
EPAct	Energy Policy Act
ERA	Energy Rated Homes of America
ERH-AK	Energy Rated Homes of Alaska
ERH-CO	Energy Rated Homes of Colorado
ERH-VT	Energy Rated Homes of Vermont
ESCO	Energy Service Company
HERS	Home Energy Rating System
HUD	U.S. Department of Housing and Urban Development
NASEO	National Association of State Energy Offices
NHBA	National Home Builders Association
RESNET	Residential Energy Service Network
SEO	State Energy Office
SHFC	State Housing and Finance Corporations
SMVRCO	Strategic, multidivisional, vertically-integrated, research-orientated, corporate organization

Part I

Chapter 1: Introduction

For decades, progressives have advocated for technological change that will lead to a more ecologically sustainable, democratic, and equitable society. However, the lack of progress has frustrated activists and observers, and has prompted a few questions. Do we really understand sociotechnical change? Assuming that we do not, how does it occur? How can we shape its direction and pace?

Progressive advocates of alternative technology lack an effective, hands-on theory of how to influence sociotechnical change. Developing such a theory is one of the main goals of this dissertation, and to do so we need to take a look at those who have been the most successful at influencing sociotechnical change in general. That is, of course, corporate organizations.

This may cause apprehension among some readers who view corporations and their profit maximization as the problem, but I encourage an open mind. There seems to be specific characteristics of corporations that could be adopted by a wide variety of organizations to promote alternative technologies without adopting other characteristics that contribute to social problems. However, I want to be upfront. The results of this study will suggest that it might be necessary to make hard choices between small-scale, consensus-based organizations and larger, more hierarchical organizations, and also to choose between merely advocating for change and actually participating in the dominant organizations and institutions that actually determine sociotechnical change. If having these choices means increasing the effectiveness of progressive advocates, then arguably these choices are worthy of consideration.

Organizations are central to the process of sociotechnical change, and this touches on the thesis that will soon be articulated. For now, let’s just say that progressives have not usually had the organizational characteristics to be effective at shaping the direction and pace of technological change. To understand what these characteristics are, we need to turn our attention to corporate organizations.

Corporations have been vastly more successful at facilitating sociotechnical change than progressive advocates of alternative technology. As corporations fundamentally restructured society through the industrial and subsequent revolutions, the United States went from a country of yeoman farmers to a nation of urbanites and suburbanites working at Wal-Mart, IBM, Web Graphics, and government offices. All major institutions have been affected. Government now affects everything we do, religion no longer does. Family structure has radically changed, and advertising now shapes our desires toward pre-packaged commodities. While these changes are noteworthy, it is the dynamic nature and unprecedented pace that are truly profound. For the first time in human history, we do not know what our lives will be like in 15 years.

What is the motor of this dynamic, ongoing social and technical change? This is an important question, because, without an understanding of the driving forces behind this change, advocates of alternative technology will have difficulty influencing it. I will suggest that the corporate organization has been the motor of modern technological change. Of course, other answers have been suggested. The most common answer is perhaps capitalism, but this is somewhat dubious when examined. Market capitalism is not recent. Defined as private property, private economic decision-making, and competition for profit, free market capitalism existed in North America before the United States was founded. Because the last one-hundred years have been characterized by a trend away from free market capitalism, it leaves much unexplained as a reason for the high rate of sociotechnical change. The state has also often been given as an answer, and indeed it has had an important impact on sociotechnical change in the United States as a purchaser of technological products and through its intervention into the economy. However, strong arguments have been made that it is usually business that largely directs the state into shaping the economy for growth and profit (e.g., Thomas 1994; Domhoff 1990). Schnaiberg (1980) argued that a partnership among capitalists, the state, and consumers to generate more material wealth has characterized the process of sociotechnical change. Despite the insight that these perspectives might offer, they all fail to consider the day-to-day activities and internal structure of large complex organizations as a driving factor behind technological change in the United States.

I suggest that the primary motor of change has been the corporate organization. In David Teece’s words, the modern “business firm is clearly the leading player in the development and commercialization of new products and processes” (1998a, 134). For-profit corporate organizations dwarf organizations in all other sectors in performing R&D and developing marketable products, and in 2004 for-profits spent twice as much on R&D than did the federal government.[16] In particular, I suggest that the strategic, multidivisional, vertically integrated, research-oriented, corporate organization (SMVRCO) is probably the most potent organizational form ever devised for technological change, and has been proficient at re-engineering the technological, economic, political, and cultural aspects of the larger sociotechnical system to better fit the products and services that they sell. In the terminology that will be used here, SMVRCOs are "system builders." The sociotechnical system is the larger set of institutions, organizations, culture, and technology that supports the use of some technologies over others (Hughes 1983; 1989).

Large corporate organizations have achieved this direct influence over technological change by acquiring the organizational capacities for system building. Three of these organizational capacities are: *strategic evaluation, planning*, *and oversight* for *control*, and also *information collection*. The fourth is to *strategically coordinate* the capacities into an efficient and comprehensive effort to reshape sociotechnical systems. The fifth is to generate *flexible financial resources to be used* for system building. Often tremendous amounts of financial resources are generated and used to expand production capacities as well as to build greater capacities for system building. As a result, SMVRCOs have ratcheted up production and consumption and increased their control over sociotechnical change.

These five organizational capacities for system building are broad and in theory can be held, to one degree or another, by any type of organization including government and non-profit. Scholars have written a great deal about how corporations systematically control their relevant sociotechnical systems (Chandler 1962; 1977; 1990; Hughes 1983; 1989; Benniger 1986). However, they have written little on the organizational ability or lack of ability of progressives to reshape the sociotechnical fabric of society.

[16] For-profit industrial corporations performed about 68.3 % of total R&D in 2003 while the federal government, universities and colleges, federally funded research and development centers, and non-profit organizations accounted for the remaining 31.7% as measured by dollars spent on R&D. However, for-profit industrial corporations were slightly less involved in funding R&D. In 2003, they funded 63.3% with the federal government accounting for 30% of the funding. Moreover, the importance of for-profit industrial organizations for driving technological change is even more pronounced when their role in the later stage of R&D to generate marketable products is examined. In 2003, for-profit industrial corporations performed 88.7% of all efforts to develop "new and improved goods, services, and processes" and funded 80.9% of it. Conversely, the federal government, universities,

This study has two goals. First, I will develop a general theory of system building and second, evaluate its utility to explain and predict the success of advocates of alternative technology. Although I will introduce new terms and focus, the thesis is essentially that progressive U.S. advocates of alternative technology have inadequate organizational capacities to shape and reshape the larger system of social, cultural, economic, political, and technical arrangements to develop marketable products. By 'general theory,' I mean that it should explain and predict successful system building for any type of organization, in any type of sociotechnical system, and for any type of new social or technical innovation. I will explore the utility of this theory through a case study of energy efficiency advocates in the residential housing industry. A general theory is important to explaining the findings of the case study because advocates of alternative technology have chosen many different organizational forms including for-profit, corporate organizations.

Advocating Technological Change

As mentioned, progressive advocates of alternative technology often have had a difficult time achieving their goals of a more environmentally sustainable society. However, this is not to say that there have not been successes. Through the lobbying efforts of the environmental movement and others, government has enacted a diverse set of laws and codes ranging from the National Environmental Protection Act, to the Clean Water Act, and to product standards for a wide range of consumer items (Dunlap and Mertig 1992). Despite these gains, there seems to be a general consensus among the progressive advocates that these laws and codes do not go far enough. Moreover, it appears that some such laws and regulations are almost never enforced (e.g., water law in the State of Washington, see Center for Environmental Law & Policy 2002) or only selectively enforced (e.g., building codes, see City of Fort Collins, 2002, and also Brown 1999).

An organizational analysis can help understand some of the structural limitations that progressive advocates of alternative technology have often imposed upon themselves. In sum, progressive advocates

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and colleges are relatively more involved in performing and funding basic research (National Science Foundation of alternative technology have typically lacked any organizational ability to directly make technological choices about the production systems and the technological products and services that are offered to consumers. Most of these choices are made primarily by businesses and also by government agencies within dominant institutions using dominant organizational forms (for example, see Domhoff 1990, Tarrow 1994, and Schnaiberg 1980). For businesses, these institutions include the market, management hierarchies, and ownership of production. For government these include statutory and administrative frameworks to regulate certain aspects of the market. Also, the dominant organizational forms for businesses have been for-profit corporations of which the SMRVCO is a dominant variety.

Historically, advocates of alternative technology have been outsiders to these dominant institutions, and often by their own choice to avoid participating in a system about which they are critical. However, this has placed them at a severe disadvantage, because they are subsequently not well positioned to exert significant direct control or often even indirect influence over corporations within the dominant economic institutions. By being an outsider, these advocates have limited their strategic choices to two options.

First, they can put economic and cultural pressure on corporate organizations by using grassroots organizing, boycotts, protests, marches, sit-ins, lobbying, and the media. However, these tactics can only generate indirect influence over corporate decision-making. *Second*, progressive advocates can put pressure on the government to, in turn, exert influence on corporate organizations and other economic actors. The government has the ability to do so by using its capacities to regulate, tax, and spend. However, the government is organizationally limited in its ability to intervene in civil society. Short of nationalizing an industry or storming a corporate head office with federal marshals, the government cannot directly control corporate decision-making any more than social movements and other citizen advocates can. It can only create a set of incentives and disincentives to influence corporate behavior and technological choice, and it remains the choice of corporate elites to comply or not comply. As noted by Schnaiberg and Gould (1994), there are a large number of ways that corporate entities can avoid regulatory compliance and the intent of government policy. Likewise, the ability of regulatory agencies

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2003).

to cajole or entice compliance out of corporate organizations is usually limited by funding levels that have been authorized by the legislative branch (Downing and Kimball 1982; Adler and Lord 1991).

More importantly, there appear to be limitations on the extent to which the state can be pressured by social movements to influence corporate behavior. Elected officials are reliant on corporate elites for electoral support and for the economic prosperity that underlines support of the rest of the citizenry (Schnaiberg 1980; Schnaiberg and Gould 1994; Domhoff 1990). For this reason, the state is often reluctant to interfere with corporate behavior. Elected and appointed officials may fear the political consequences of aggressive regulations and their enforcement (Hawkins 1984; Gould 1991; Schnaiberg and Gould 1994).

Sidney Tarrow has another way of stating these limitations on protest activities. Social movements can be effective at creating an atmosphere of discontent that puts pressure on corporations and government for progressive technological change. In this way they have influence, but they usually have little or no control over the actual kind of change that results. Government and, to a larger degree, corporations make that decision (Tarrow 1994). Typically, corporate managers are the only decision makers that have a direct say over which technology is developed and marketed. This is because they alone have the ownership and managerial control over the means of production to actually bring about sociotechnical change. Government agencies can set procurement standards, give tax breaks and subsidize R&D to encourage the private sector to develop new technologies and build sociotechnical systems, but for the most part it cannot develop and build them. Furthermore, Collin Hays (1994) suggests that the degree of progressive sociotechnical change that corporations and government undertake is often only enough for government and corporate elites to symbolically claim that change has occurred.

Although their efforts have not been futile, these traditional social movement strategies have failed to fully participate in the basic processes through which sociotechnical change actually occurs. These processes are an insider’s game that belongs to SMVRCOs and other firms that control the production process with usually minor interference from government. These conservative doers, not the progressive advocates of doing, have been the primary motors behind technical change.

How have they steered and otherwise affected sociotechnical change? There are of course many theories of large-scale sociotechnical system change. The two that I prefer are system building and neo-institutional theory. The organizational based theory of s*ystem building*, as mentioned above, captures the intentional aspects of technological change. It focuses on the ability of organizations to collect information about their relevant sociotechnical system, rationalize what changes in the system need to be made, and intentionally use their organizational capacities to reshape system arrangements.

Because it is unusual for one organization to control an entire sociotechnical system, a network of organizations, both competing and cooperating with each other, appears to be involved in most system building. Often organizations in a network with each other will adopt the same organizational structures and strategies through the influences of other organizations and will come to resemble each other. In other words, they become isomorphic. Fennell (1980) and DiMaggio and Powell (1983) suggest there are two processes of isomorphism. When they come to resemble each other through rational analysis of what works and does not work and through competitive pressures, this type is called *competitive isomorphic change*, which is consistent with the intentionality of system building. The other type is *institutional isomorphic change* that involves non-rational processes that lead to conformity among organizational actors. Specifically, it denotes a process toward conformity driven by organizations striving for legitimacy, trying to mimic successful organizations, and/or group thinking by staff from the same professional backgrounds. These processes can occur regardless of the presence or absence of any evidence that a set of organizational structures or strategies are actually effective (DiMaggio and Powell 1983). Although not intended as a systems theory, its utility in explaining organizational change seems appropriate to explain aspects of how organizations evolve as they engage in system building and make changes in their strategy.

Whether through well thought-out system building or through isomorphic processes, SMVRCOs exert a tremendous influence on society, both directly and indirectly. Charles Perrow[17] and others have

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[17] Although Charles Perrow is best known for his work on other aspects of complex organizations, he has been a long-time advocate of organizational theories of large-scale, social change.

argued that large-scale corporate organizations have internalized a large portion of those parts of the economy that are crucial for their success. They have done so through horizontal integration and the vertical integration of downstream manufacturing and the upstream integration of distribution and marketing firms as well as integration with research and development capabilities. Of course, a corporation can never internalize a large share of society. However, it can still significantly influence the remainder of society through its organizational capacities for gaining information about, controlling, and coordinating the external system. This includes marketing research to control consumer demand, public relations to control public opinion, and lobbying to shape government regulations, policies, tax structures, and subsidies (Perrow 1991, Chandler 1977, 1990; Schnaiberg 1984; Schnaiberg and Gould 1994; Beniger 1986, Hughes 1989).

As individuals on the outside of the system, progressive advocates of alternative technology have been able to participate in the core processes that determine the direction of technological change. In light of their concerns for the environment, peace, and economic equality, they are desperate for a new way to shape corporate and other economic behavior to encourage sociotechnical change for more energy efficiency, less natural resource use and pollution, and more economic equality.

Participant-Advocate Approach to Facilitating Sociotechnical Change

Over the last three or four decades, there has been a trend for alternative technology advocates and the environmental movement in general to move away from being the outsider protesting the dominant economic and political institutions, toward being a relative insider with some access to decision-making (Mol 1995; Spaargaren 1997; Dunlap and Mertig 1992) or toward groups that have the ability to be both an insider and an outsider (Sonnenfeld 2002). This appears to be part of the maturing process that social movements undergo, which has been noted by other social scientists (Albrecht 1976; Tarrow 1994).

However, some advocates of progressive technology have gone even farther. In addition to alternative technology advocates allying themselves with economic actors, some of these advocates are themselves becoming economic actors, and constructing their own alternative production processes in juxtaposition to, or in combination with, the conventional production and consumption processes that are dominated by current organizational and institutional elites. In other words, they are participant-advocates. Examples of such efforts include community-supported agriculture (DeLind and Ferguson 1999), organic agriculture (Hassanein and Kloppenburg 1995), sustainable forestry certification systems (Gilley 2000), recycling, and also the efforts by participant-advocates of green-building. Hawken et al. (1999) makes a similar argument and gives additional examples.

Another example, and also the focus of a case study in Chapters 9 and 10, is the advocates of the Home Energy Ratings Systems (HERS) and Energy Efficient Mortgages (EEMs). An EEM is used to finance energy efficient technology through the mortgage process. It gives homebuyers better terms on their mortgage including the ability to borrow extra money to buy and make an existing house more energy efficient, or extra money to buy a new home that is energy efficient. The primary way that homes meet the energy efficiency standards to qualify for an EEM is to have a HERS rating conducted. A HERS rating is an assessment of the energy efficiency of a home, which is provided by HERS organizations (which already existed in the 1980s) that specialize in assessing the efficiency of homes and making recommendations on the cost effectiveness of energy efficient improvements. HERS ratings are also used to provide information on energy efficiency to homebuyers, meet energy codes, and help with other tasks.

Advocates of HERS and EEMs were not just advocating their use, but were participating in the residential housing industry as economic actors, building the needed system arrangement and using EEMs and HERS in a market environment. By the late 1990s, advocates of HERS and EEMs had constructed the basic institutional and organizational infrastructure to use HERS to assess energy efficiency and EEMs to finance that energy efficiency. However, it was not very well integrated into the rest of the system, and few EEMs and HERS were used. From the late 1990s to the present, these advocates spent their efforts trying to integrate this infrastructure into the residential housing industry at the institutional level and at the level of day-to-day organizational routines.

In the instance of HERS and EEMs and in each of these other examples, the participant-advocates are not merely advocating changes in the sociotechnical system, but are also designing and implementing their own systems arrangements with little or no cooperation from corporate elites at the beginning. In doing so, they are starting to influence technological choices in these sectors of society by creating new technical arrangements, organizational forms, distribution networks, and sets of standards to convey information to buyers and sellers about the environmental impacts of technological products and services. Moreover, corporate organizational elites have begun to adopt some of the alternative technology, distribution networks, organizational forms, and/or systems of standards used by the advocates of alternative technology; or they instead have set up their own organizations, networks, and standards that mimic those of the alternative technology advocates. In other words, the initial system building by participant-advocates to create a more ecologically sustainable system appears to have started processes of competitive and/or institutional isomorphic change where corporate elites have adopted these technological and institutional innovations as their own and engaged in further system building.

The Focus of this Study

This study is organized around the goals of developing and empirically evaluating a new, hands-on, organization-based, general theory of system building that can be useful for advocacy groups that have otherwise been unable to significantly influence technological change. This theory is intended to be a practical tool for organizations to engage in system building as well as for scholars to explain and predict sociotechnical change by viewing organizations as the central force shaping the direction and pace of technological change.

This theory will be evaluated through the thesis as follows. *Progressive advocates of alternative technology have lacked the organizational capacities for collecting information about, controlling, and coordinating the parts of their relevant system, as well as for the strategic planning and the financing of system-building activities that are necessary for successfully developing marketable products.* By alternative technology, I mean technology that has a small market share and is not well supported by, nor used in, existing system arrangements. By progressive advocates of alternative technology, I am referring to those who promote technology that is less damaging to the environment or offers greater social and economic equity than more commonly used technology. The progressive advocates that I will study are advocates of Energy Efficient Mortgages and HERS ratings.

This thesis is premised on two assumptions. The first is that the existence of supportive sociotechnical systems is the reason why technologies succeed and the lack of them is why they fail. By a sociotechnical system, I am referring to a functionally interrelated set of technical and social components. The technical world does not have a life of its own, but is embedded in the culture, organizations, and institutions of society, which altogether make the sociotechnical system. This sociotechnical system supports the use and diffusion of certain technologies to the exclusion of alternatives. A systems perspective has been widely used in the social study of technology by various disciplines (e.g., Mumford 1934; Marcuse 1941; Beniger 1986; Bijker, et al. 1987; Hughes 1989; Rosenbloom and Christen 1998; Hagström and Chandler, 1998).

The second assumption is that sociotechnical systems are to a large degree intentionally constructed by organizations with a vested and/or ideological interest in promoting particular technologies. The captains of industry have long known the importance of system building whether for the railroad, the electrical grid, computers, or the automobile. Henry Ford, Alfred P. Sloan at General Motors, and their allies and successors engineered, financed, and advocated a system of factories, auto and auto part dealers, mechanics, financial credit for customers, petroleum refineries, highways, traffic laws, motels for travelers, and the American culture of the automobile (see Chandler 1990 and Hughes 1989). Without such a supporting sociotechnical system, the internal combustion automobile might not have succeeded against its historical competitors (i.e. the horse, electric car, and steam-powered car), despite that most people now consider the internal combustion engine to be the superior technology (see Cowan 1996 for a history of the automobile). Indeed, building a system is a proven method to advance new technologies. In one form or another, system building is the only way that technology ever widely succeeds.

Both Hughes (1989) and Callon (1987) pointed out that, as a sociotechnical system develops, it must contend with certain components that are less effective and reliable than others. These weaker components will limit the development of the entire system and hold back technological change. Callon

(1987) labeled these as “points of resistance.” However, system builders are not all equally successful at removing points of resistance and building systems. It appears that many system builders do not have an adequate set of organizational capacities for removing points of resistance and successfully building the systems that will support the technologies that they manufacture and sell, or that they advocate.

I am referring to organizational capacities as a set of organizational routines and structures within that organization that are used to shape the direction of their relevant sociotechnical system. I suggest that there are five of these organizational capacities:

- To gather information on the current state of the sociotechnical system (Beniger 1986; Witteloostuijn 1997).
- For strategic evaluation, planning, and oversight of system building efforts (Chandler 1962; 1990; Hagström and Hedlund 1998; Dougherty and Corse 1997).
- To obtain financial resources that can be used for system building (Lazonick and West 1998; Chandler 1990; Teece and Pisano 1998).
- To control the cultural, economic, political, and technical dimensions of a sociotechnical system (Hughes 1989; Beniger 1986, Schnaiberg 1984; Schnaiberg and Gould 1994).
- To centrally coordinate all of the above capacities into a single, system-building effort (Chandler 1962; Fujimoto, 1998; Teece 1998a).

Is it possible for progressive advocates to acquire or internally build the same capacities for system building that SMVRCOs have? To one degree or another they probably can. Again, the concept of organizational capacities is quite flexible and can take many forms. For example, the capacity for control can in theory be built through many different organizational routines, structures, and network relationships that could be conducive to the organizational forms of participant-advocates of alterative technologies. However, their adaptations are always constrained by their views about themselves, their organization, and broader society. Likewise, as is any other organization, they are constrained by their internal organizational structure and culture, and the broader systems arrangements at any particular time.

However, one barrier is likely to be ideological. Organizational capacities for successful system building usually place a premium on concentrations of power, hierarchies, growth, standardization, and working with the existing system. These contradict some of the values that many progressives strongly hold—pluralism, individuality, consensus, and small-scale community organizations.

Although I have mixed feelings about it, one interpretation of my thesis is that Schumacher's "small is beautiful" thesis (Schumacher 1989) should be turned upside down. There are many very redeemable things about small-scale, community-based organizations and their technology. Unfortunately, it has not been an effective model for facilitating sociotechnical change on a wide scale, particularly when competing directly against SMVRCOs in modern market economies. When small-scale, community-based organizations do succeed, it is likely because of uncommonly devoted and clever participants in these organizations and SMVRCOs have yet to venture into the market niche of these smaller organizations.[18]

The Organization of this Study

I will develop the organization-based theory of system building in Chapter 3 by drawing off of existing theories of sociotechnical systems and of society and technology in general. As noted above, a key difference between this new organization-based theory and the older theoretical perspectives is that this theory explains sociotechnical change through the capacities of organizations to control and coordinate the development of sociotechnical systems including the introduction of new technologies. Organizations, not individuals, are the most important actors shaping the direction of sociotechnical systems. In particular, organizations with a well-developed set of all five capacities that are matched to the purpose of controlling and coordinating the major parts of its relevant sociotechnical system are theorized to be the most successful at system building.

This does not mean that it is necessary for there to be a single organization that controls and coordinates all of the parts of a sociotechnical system or even that all the organizations be massive, vertically integrated organizations for successful system building to occur. However, it does broadly mean that the kind, size, and sophistication of the organizational capacities for system building will

[18] The implications for democracy and the concentration and abuse of power are discussed by Chandler (1980, 38, 166).

greatly affect the characteristics of that system. This includes the pace, direction, and kind of changes that the system undergoes and the ease with which new inventions are introduced. Certain types of systems are likely to need different organizational capacities. Nevertheless, without large-scale, complex organizations we would not have many of the large-scale, complex sociotechnical systems that we associate with modern society.

However, by the end of Chapter 3, this theory will still be at a high level of abstraction and also vague as to how organizations actually go about introducing new technologies and system building in general. It will not be developed well enough to evaluate the thesis, or to make useful predictions about technological change, or to be practical for policy makers and system builders to use. The most pressing of these matters is that the theory will be too vague to allow us to recognize many of the various ways that each of the five organizational capacities can manifest as structures within actual organizations, to explain which of these structures are the most effective for system building, and for what kind of sociotechnical systems.

To build the additional theory that is needed, an inductive approach will be used in part II of this study in addition to the deductive approach that will be used during the case study of participant-advocates in the residential housing industry in part III. Chapters 4 and 5 will primarily use the inductive approach and will do so by examining the organizational development of the modern, large, complex corporate organization as it engages in system building. This will primarily be used to build a more specific theoretical understanding of the type of organizational structures that can be successfully used by organizations as capacities for system building, for what types of systems, and to what effect. Then, the remaining chapters, particularly numbers 9 and 10 will use a more deductive approach, using the general theory developed in the previous chapters. As mentioned, this study's thesis will be evaluated through a case study of energy-efficient technology in the residential housing industry.

The historical corporation was chosen as the organizational form to be examined in Chapters 4 and 5 and to generate additional theoretical constructs. However, why study historical corporations and not another organizational form? *First,* SMVRCOs are arguably the most effective organizational form yet developed for system building, and it would be a serious oversight to build a general theory of system building without including an understanding of how capacities manifest in these organizations, how these are used for system building, and to what effect. *Second*, progressive advocates of alternative technology have been increasingly participating in the dominant organizations and institutions, and often adopting the corporate form and/or some of its market strategies and tactics. Thus, to evaluate this study's thesis about progressive advocates, it is crucial to have a theoretical understanding of how corporations go about system building. *Third*, corporations are one of the most thoroughly studied organizational forms in the social sciences, and thus the secondary data from these studies will provide an excellent place from which to build additional theory. Many of these studies of corporate organizations have focused on the relationships between corporations and their sociotechnical systems. However, much of this research has usually not focused on how corporations explicitly go about system building. Most studies focus on the related phenomenon of how corporations shape the sociotechnical system to maximize profit and growth.

In Chapter 4, I will discuss the first major period of corporate system building from the civil war until the very beginning of the 1900s. This was a period when inventors/entrepreneurs were assembling the basic parts of sociotechnical systems to support their technical inventions as marketable products. These entrepreneurs directly and indirectly set up organizational structures for downstream production, transportation, distribution networks, sales units, and retail outlets, which were often set up as either internal operating units within their organization or as external organizations. In either case, these inventors/entrepreneurs often lacked effective ways to control and coordinate these new parts of the system to efficiently produce and sell their product. They did eventually find solutions. Somewhat haphazardly, through mergers, acquisitions, and internal reorganizing, corporate management gained centralized control over many of these parts of the system and integrated them into single management hierarchies. Each corporate organization had a set of functional departments that were specifically for purchasing, production, distribution, and sales, and a strong head office for the entire organization that directly controlled and coordinated the day-to-day activities of these functional departments. This came to be known as the functional-form of organization, and appears to have been essential to the low-cost, mass produced goods that were mass distributed and sold to the mass market that characterizes the 1900s.

Two important theoretical points can be taken from Chapter 4. *First*, at the end of the 1800s, internal management hierarchies proved to be superior organizational capacities for control and coordination than that of network arrangements. *Second*, the management hierarchies of the functional-form were good for efficiently running an existing set of system arrangements for purchasing, production, distribution, and sales, but they did not produce much technological change. It appears that in order for an organization to be successful at system building over the long-term, they needed to have specific capacities for building new system arrangements as opposed to just maintaining the existing system. This last point will be further developed in Chapter 5.

Corporations that were organized into the functional-form of organization were rather static in their production process and the products they sold. Chapter 4 shows examples of how they were quite good at controlling and coordinating existing system arrangements, but in Chapter 5 I discuss how they lacked a management structure that could dynamically respond to changes in their environment or control the direction and pace of change. They lacked any real routines that focused staff on invention and innovation. Moreover, everyone's livelihood and many of their personal identities were vested in current production technologies. This made it very unlikely that significant innovation would occur.

The static nature of corporate organizations started to change in the first few decades of the 20th century, and a major impetus was the Great Depression. Faced with bankruptcy from a drop in demand, many corporations were prompted to diversify their product lines and find new markets for existing goods. Essentially, corporate organizations learned how to adapt to changing circumstances and be proactively innovative. They built offices of R&D and marketing, which became two of their most important organizational structures for controlling and coordinating sociotechnical change.

However, the larger volume of sales and primarily production and sale of diversified product lines overwhelmed the management of the functional-form of organization. In particular, it caused an overload of information and decision-making in the central office. To address this problem, corporate organizations decentralized their day-to-day decision-making by creating separate divisions for each product line that each had their own functional departments and were delegated full authority to make operational decisions. This had the extremely important, but largely unintended consequence of freeing up time, staff, and resources in the central office for long-term system-building activities, and it created a central office that was much more powerful in large-scale system building.

The result was a new form of corporate organization—the strategic, multidivisional, vertically integrated, research-oriented, corporate organization (SMVRCO)—that became the dominant form for large, industrial U.S. corporations. Because the central office was not entirely pre-occupied with, and no longer had such a strong vested interest in the day-to-day operational activities of their firms, it was much more able to act with the long-term interests of the whole organization in mind. Likewise, it had more strategic flexibility to engage in evaluation, planning, and oversight of system building. R&D laboratories were centrally controlled by the head office of the firm but were still integrated with production and other parts of the firms. This allowed them enough autonomy from production to pursue novel inventions and yet still have the information and authority to integrate these new inventions into the rest of the firm. These organizational innovations gave corporate management a much greater degree of control over the expansion and elaboration of their respective systems. This included the ability to internally generate new technology and strategically fit it into the larger sociotechnical system.

The important theoretical point is that if an organization is going to be successful at system building, they need to construct specific structures for system building. These include sets of routines for fitting new technical and social innovations into the existing system (such as R&D and marketing capabilities), for strategic evaluation, planning, and oversight for the organization as a whole, and for generating and flexibly allocating financial resources for system-building activities.

However, corporate leaders usually did not engage in any well thought-out plan to develop these organizational capabilities to control and systematize society through system building. Instead, they made piece-meal changes to address challenges as they arose, often unaware of larger consequences. Throughout these chapters, the neo-institutional view of organizational decision-making is embraced.

Not all industries went through this same process of consolidation, vertical and horizontal integration and developing sophisticated capacities for system building. The residential housing industry has yet to go through such a process, which will be discussed in the case study of Part III. Specifically, I will elaborate in Chapter 6 on how certain social and technical characteristics of residential dwellings—large, difficult to transport, technically complex products that are culturally expected to be highly customized—have made it very difficult for construction firms to develop into large, centralized, firms with mass production, distribution, and marketing facilities to build and sell these products. It appears that the centralization of production facilities is one of the key antecedents to vertical integration, the multidivisional-form of organizations, and developing internal marketing and R&D capabilities, which most of the residential housing industry has not embraced.

As I will then discuss in Chapter 7, the residential housing industry has remained extremely decentralized and fragmented, and firms have very few organizational capacities for system building, which appear to be some of the main reasons why builders have had a very difficult time introducing complex, systematic innovations. Historically, builders have not had much control over the construction process, little or no quality control, and rarely their own R&D laboratories to integrate new technological inventions into the construction process. Most do not even have their own marketing capabilities to integrate new building technologies with market demand. A similar situation is true for the existing housing side of the residential housing industry, as will be discussed in Chapter 8. In addition to the physical problem of retrofitting existing homes, it appears that there are few organizations with the necessary capacities for introducing systematic innovations. However, this side of the industry has also seen the emergence of some larger firms specializing in remodeling and retrofitting that are consolidating and integrating with other parts of the industry.

One of the most important implications of these chapters is that network relationships within the housing industry do not appear to often result in successful system building. This is because most firms in the industry lack the capacities to be valuable to participants in a network of system builders. Although every organization will need to outsource for some organizational capabilities to one degree or another, it is not a viable option if all your network partners lack the organization capacities that you need.

When technological change does occur in the housing industry, most of it appears to be for autonomous innovations, such as new glues, paints, fasteners, wood products, equipment, and pre-fabricated components that are easily substituted for older technologies with little or no change in the design of homes or the larger sociotechnical system. Systematic innovations appear to be rare. However, most of these autonomous innovations cannot fully be attributed to system building efforts of the core organizations in the residential housing industry. Most of these inventions and innovations appear to have been generated from the periphery of the industry by manufacturers of construction inputs, not by the builders and contractors.

It appears to be very difficult to fit systematic innovations into the larger sociotechnical system because firms in the residential housing industry are too small and fragmented to have well-developed organizational capacities for system building. A large percentage of alternative, energy-efficient technologies are systematic innovations such as passive solar heating, airtight construction, and super efficient HVAC systems. To successfully introduce these into the sociotechnical system on a wide scale, fundamental changes must be made in how homes are designed, built, valued, financed, and used. However, the case study in Chapters 9 and 10 is an example of participant-advocates of energy efficiency engaging in this kind of system building.

Chapters 9 and 10 will evaluate the thesis that *a lack of organizational capacities for system building has been a reason why progressive advocates of alternative technology have not been more successful at developing marketable products*. Specifically, I focus on the closely interrelated efforts of progressive advocates to encourage the use of home energy ratings systems (HERS) and energy efficient mortgages (EEMs) to encourage the purchase of energy efficiency technology from the early 1980s to 2005, such as airtight construction, window screens, super efficient HVAC, and well insulated dwellings. As mentioned, HERS ratings are a state-of-the-art assessment of the energy use of residential dwellings, which can be used as information by builders, home buyers, mortgage lenders, code officials and others.

EEMs are a mortgage product that provides incentives to homebuyers to purchase energy efficient homes or to buy a home that is inefficient and make it efficient. Analogous to the inventor/entrepreneurs in the 1800s, the participant-advocates of HERS and EEMs have been creating and piecing together new parts of the system to support alternative technologies. As we shall see, both HERS and EEMs are highly systematic innovations that will require integration with most of the major parts of the residential housing industry if they are to be used to their fullest potential.

For a few reasons, a case study of HERS and EEMs provides a useful test for the thesis of this study. *First*, the organization-based theory of system building predicts that systematic innovations such as HERS and EEMs that are in turn used to facilitate systematic technical innovations will be the most difficult to successfully introduce to a system. This is exactly the type of sociotechnical change where the five organizational capacities for system building should be the most needed. *Second*, the participant-advocates of EEMs and HERS have undertaken rather aggressive system building. The participant-advocates of HERS and EEMs are attempting to make some fundamental structural changes in how the U.S. residential housing system goes about assessing, financing, and marketing energy efficient technology, and ultimately how it chooses the technology. This is a complex set of system building goals that involves fairly complicated sets of organizational and institutional innovations that let us explore many different aspects of the system building process.

Chapter 9 takes a national “bird’s eye” point of view of system-building during a set of pilot projects and a study conducted by the DOE and the FHA. This will allow us to assess the extent to which there were effective organizational capacities for system building at the national level to both construct a basic infrastructure for HERS and EEMs and integrate those structures into the residential housing system.

Conversely, Chapter 10 will look at system building from the viewpoint of individual organizations at the community level. First, two different approaches to integrating EEMs into the residential housing system are contrasted and compared and then used to evaluate the thesis. Second, two different approaches to integrating HERS into the system were used for a similar evaluation.

Chapter 2: Methodology

Once again, the thesis of this study is that *too few organizational capacities for system building has been a reason why progressive advocates of alternative technology have not been more successful at developing marketable products.* This will be evaluated through a case study of participant-advocates of energy efficiency who have been building a set of systems arrangements to support the use of HERS and EEMs and thus encourage the purchase of energy efficiency technology in the U.S. residential housing system. The case study is restricted to system-building activities from the early 1980s to 2005 in the lower 48 states. As a simplifying assumption and because the two states are outliers, Hawaii and Alaska were omitted from the case study. Hawaii was omitted because its mild climate seems to have prevented any significant interest from participant-advocates of HERS and EEMs. Alaska is omitted from this case-study because the set of dynamics characterizing system building in the state have been very different from the lower 48. The state government of Alaska has played a much stronger, central role in the system building than in other states.[19]

Unit of Analysis

The unit of analysis is the residential housing system. This sociotechnical system includes both a supply side and demand side for the single-family, detached residential dwelling. The *supply side* is essentially the residential housing industry and its organizations, institutions, culture, and technologies

[19] The state of Alaska has played a very significant role in building systems arrangements to support the use of HERS and EEMs. It created an organizational infrastructure to rate homes, train raters and contractors, and market HERS and EEMs. It also put in place a very aggressive set of institutional arrangements to support the use of HERS and EEMs including a very strict building code that can be met with a HERS rating, required compliance with the building code before a mortgage can be obtained through the Alaskan Housing and Finance Corporation (which has a large market share), offered interest rate reductions for EEMs, and required that all contractors take a course on energy efficiency. In 1995, 83% of all new construction was HERS rated. The circumstances that led to these actions by the state were a bit unique. The first is extremely high energy prices. The second, a political crisis triggered by a boom and bust cycle in the housing industry and subsequent defaults on mortgages that left the state-chartered Alaska Housing Finance Authority in possession of hundreds of millions of dollars of poorly constructed, energy inefficient, substandard housing that could only be placed on the market after thousands of dollars in improvements. This and the public outcry over the "shoddy" housing construction during boom period in the early 1980s (including some homes without any insulation) seems to have compelled the state to take action to improve the energy efficiency of the housing stock (Farhar and Eckert 1993; Collins 1997; and phone interview with staff at AKwarm).

that are involved in the production, financing, selling and reselling of residential dwellings. The organizations and firms are primarily those engaged in construction, design, maintenance, retrofitting, remodeling, selling, appraisal, consulting, inspection, and financing of existing and new homes, as well as on the periphery of the industry such as government agencies, the manufacturers of construction inputs, and non-profits. Of course, most of these organizations use primarily conventional building technologies, and others advocate and use alternative technologies. Institutions include government regulations about real estate transactions, state and local building codes, and informal industry standards for products and services. The *demand side* is the organizations, institutions, culture, and technologies that are involved in the use of residential dwellings. This includes the households of home buyers; the cultural values, attitudes, and beliefs that shape the domestic use of residential dwellings, the products and services that are used in close association with residential housing technology such as appliances and electricity, and the firms that provide these products and services that usually lie on the periphery of the industry such as appliance manufacturers and utilities.

The setting of boundaries around a system is always somewhat arbitrary, and this sociotechnical system could be more broadly defined to include other organizations and institutions. I will sometimes view the relevant sociotechnical system as embedded in a larger metasystem with which it has interactions. This meta-system is essentially the remainder of economic, political, and social institutions, organizations, and culture of a society that is not included in the residential housing system.

System-Building Organizations and Other Organizations

Many of the organizations within the residential housing system are system builders focused on the success of particular technologies, but most are not. Most are participants in the system that have organizational capacities for maintaining existing systems arrangements, but not specifically for system building to any significant degree. Below is a description of the types of system-building organizations that actively focused on the success of HERS and EEMs. The general term for the types of organizations directly or indirectly involved in providing HERS ratings is a *HERS organization*. There are several kinds. *First*, there are hundreds of HERS raters around the country that gather data on the thermal characteristics of homes that is run through a computer model to generate ratings. Historically, most have worked part-time as one-person businesses, but many have been adopting more sophisticated organizational models over the years. *Second*, HERS providers put the data collected by HERS raters into a computer model, generate ratings, and print out the final rating certificates. Although sometimes the raters do the modeling themselves, HERS providers are always responsible for checking the data and ratings for errors, completing additional paper work, performing quality control, and also marketing HERS ratings to the residential housing industry. Historically, HERS providers have been small organizations or government offices of usually one to six people, but have been adopting more complex organizational forms as well. *Third*, there are HERS software developers that sell the computer software to model energy use and determine energy efficiency. This software is called a HERS rating tool. *Fourth*, in 2002, HERS training providers emerged as another organizational type to provide trainings for individuals to become HERS raters and also for realtors, bankers, and appraisers about energy efficiency, HERS, and EEMs. Prior to 2002, HERS providers were responsible for these trainings, and now many organizations operate as both HERS providers and a HERS training providers.

There are other important organizations. *Fifth*, EEM facilitators promote and assist the use of EEMs for existing homes. They help home buyers coordinate the activities of mortgage lenders, HERS raters, contractors, and realtors during the EEM process. *Sixth*, trade associations for HERS and EEM participant-advocates have included the HERS Council and the Residential Energy Services Network (RESNET). The latter is the current accreditation agency for HERS systems.

There are also other organizations that are relevant to the system building endeavor that are not considered to be system-building organizations per se. These include, *first*, social movement organizations and trade associations that function as advocates of HERS and EEMs but less so as participant-advocates or system builders, such as the National Association of Home Builders, Alliance to Save Energy, and Natural Resources Defense Council (Farhar et al. 1996; 1997; and 1993). *Second*, various government bodies have an influence on the system-building process, but it will be assumed that they are not organizational system builders per se. Instead these organizations are viewed here as only political organizations that affect the system building processes primarily through political routines instead of through organizational capacities for system building. This assumption is made for theoretical reasons and also to simplify the analysis. The theoretical rationale is given in Chapter 3, and evidence of the reasonableness of the assumption is given later in this chapter. These government bodies include the Department of Energy (DOE), state energy offices (SEO), and state housing finance agencies (SHFA) which were crucial in helping to set up the original HERS providers and helping build networks between HERS providers and the rest of the residential housing industry.

Directly below is a list of organizational capacities that are posited to be necessary for successful system building. While these are referred to as organizational capacities, each is actually a set of routines that are knit together by organizational structures, as previously mentioned.

- The capacity to gather *information* on parts of the sociotechnical system.
- The capacity to *strategically evaluate, plan, and oversee* system-building.
- The capacity to *finance system building*.
- The capacity to *control* the relevant parts of a system.
- The capacity to *coordinate* the relevant parts of the system.

How will organizational capacities for system building be recognized as such? As will be mentioned in Chapter 3, organizational capacities are, by necessity, a vague term. Many different sets of routines can be used to gain information about, plan, control, and coordinate the parts of a sociotechnical system. For this reason, the organization-based theory of system building is, to a significant degree, a grounded theory—a heuristic to “systematically” gather data and simultaneously build theory (Glaser and Strauss 1967, 2). In the case study, both theory and data will be used in an ongoing dialogue with each other to explain emergent system phenomena, although in a much more deductively than in Chapters 4 and 5.

Also, it needs to be recognized that most organizations are *not* internally structured into units (e.g., departments) composed just of capacities for control or gathering information. Instead, most are structured into functional units, such as purchasing, manufacturing, and R&D with a variety of routines for information, control, and coordination and sometimes for generating financial resources and strategic planning. For example, R&D departments are functional units that have routines to collect information about, control, and coordinate technological development, and often routines for strategic planning.

This is useful because case study data is often of different levels of complexity and detail. Sometimes very broad information was found on specific departments and other times on much more specific behaviors that make up individual routines. Therefore, the above organizational capacities will be recognized and described in this case study in a number of ways depending on the data available, and what makes sense for analysis. Organizational capacities will be primarily discussed and studied as . . .

- sets of organizational routines or processes (Feldman 2004) including functional/operating units (e.g., central offices, manufacturing departments, office of strategic planning, and R&D programs),
- specific organizational routines (Pentland and Feldman 2005),
- organizational routines reduced into specific behaviors (Pentland and Feldman 2005), and
- positions that individuals hold within organizations and their associated routines.

The organizational capacities of the participant-advocates of HERS and EEMs will be evaluated to determine how well they have shape the larger sociotechnical system in a direction that is supportive of HERS and EEMs and thus alternative technology. This causal relationship will be judged according to the existence of 1) theoretically adequate organizational capacities for system building 2) that appear to be intentionally used to alter systems arrangements, 3) then result in a change in the sociotechnical system including the use of alternative technology, and 4) other evidence of cause-effect relationships that has been documented, reported, or observed. As defined earlier, alternative technology is technology that has a small market share and is not well supported by, nor used in, existing system arrangements.

Data Collection and Management

As typical of case-study approaches (Ragin and Becker 1992), this one will use a number of different data sources and methods of data collection. A documentary analysis of government and NGO reports will be heavily used to address the historical development of the HERS and EEMs, relevant organizations, formal institutional arrangements, and other aspects of system building. However, seldom do formal institutional arrangements work as advocates and policy makers intend. Thus, telephone interviews, face-to-face interviews, surveys, and observation techniques (Lofland and Lofland 1995; Marshall and Rossman 1989) were also used to assess the development and use of EEMs and HERS.

The field research and the telephone surveys of lenders in 2000 and 2001 were primarily exploratory. Later when the thesis of this study was formed, the data collected during the exploratory phase was sorted into the following categories and similar was done of all subsequent data that was gathered regardless of the collection method used. These categories were 1) evidence of any or all of the five organizational capacities, 2) evidence of perceived problems with existing system arrangements, 3) evidence of actual problems with existing system arrangements, and 4) evidence of successful system building such as new organizational and institutional structures established. However, there was additional data that was sorted into the category of 5) contextual information on the residential housing industry that appeared to impact HERS and EEMs.

Data Collection in the Exploratory Phase

Field techniques: Work in the field during primarily the summer of 2000 was exploratory, and interviews were conducted before the thesis of this study was formulated and without a predetermined set of questions. The techniques that were used included face-to-face interviews, obtrusive observation, and a small amount of participant observation (Lofland and Lofland 1995; Merton et al. 1990) with the purpose of gaining a deeper understanding of the development of HERS and EEMs. The questions were structured around the issues of how participant-advocates of HERS and EEMs were going about building new systems arrangements for HERS and EEMs, how HERS and EEMs were used in actual practice by the housing industry, problems encountered by HERS and EEM advocates and other industry participants, and solutions used. Field notes were used to gather data, and two years later that data was sorted into the categories listed at the top of this section.

The primary field locations were Denver, Colorado; Burlington, Vermont; and Mountain View, California and were studied in June, July, and August of 2000. These locations were chosen because of a substantial level of historical and contemporary EEM and HERS activity, which was assessed primarily using data from NREL, advice of industry participants, and phone interviews with eighteen employees of state energy offices. Three other field locations that were chosen and studied out of convenience from 2000 to 2003 include Lincoln, Nebraska; Pullman, Washington; and Seattle Washington.

The time spent observing and conducting face-to-face interviews was roughly divided into four-fifths of the time in offices of HERS providers and one-fifth of the time spent with HERS raters and other industry participants in their offices and work-sites. Face-to-face interviews and a few supplemental phone interviews were conducted with a total of eight staff members of HERS providers, five HERS raters, six builders, six specialty-trade contractors, nine loan officers and banking professionals, two realtors, four appraisers, one code official, and four EEM facilitators.

Surveys of lenders: During the same time that field work was being conducted, two populations of loan officers were surveyed and administered a telephone questionnaire. This was also exploratory research. One survey was of a population of Colorado E-Star loan officers who received training on EEMs and volunteered to participate in the E-Star program (see Appendix A), and will be referred to as the 2000 Survey of Colorado E-Star lenders. The other was of Vermont loan officers that completed EEMs in conjunction with the facilitation services of Energy Rated Homes of Vermont (see Appendix B), and will be referred to as the 2000 Survey of Vermont EEM lenders. The goal of both surveys was to assess the extent to which these populations of mortgage lenders had used EEMs, how they perceived and used EEMs, and problems they faced. See the appendixes for more discussion on the methods used, the questionnaires that were administered, and a selection of the data collected.

Data Collected Specifically to Evaluate the Thesis

Documentary analysis: Analysis of the large volume of written information about HERS and EEMs provided one of the most valuable sources of information about the development of HERS and EEMs was used to evaluate the thesis of this study. Extensive use was made of reports and web pages from the Department of Energy, Department of Housing and Urban Development, the Environmental Protection Agency, and State Energy offices. The most important of these were seven reports published by the National Renewable Energy Laboratory:

- *A National Program for Energy-Efficiency Mortgages and Home Energy Rating Systems: A Blue Print for Action*, 1992.
- *Going National with the HERS and EEMs: Issues and Impacts: The collected Papers of the National Collaborative,* 1992.
- *Energy-Efficient Mortgages and Home Energy Rating Systems: A Report on the Nation's Progress*, 1993.
- *Linking Home Energy Rating Systems with Energy Efficiency Financing: Progress on National and State Programs*, 1996.
- *Case Studies of Energy Efficient Financing in the Original Five Pilot States, 1993-1996*, 1997.
- *National Status Report: Home Energy Rating systems and Energy Efficiency Mortgages,* 2000.
- *Pilot States Program Report: Home Energy: Rating Systems and Energy-Efficient Mortgages*, 2000.

Reports, web sites, and news letters of HERS providers, Residential Energy Services Network, the HERS Council, and EEM facilitators were also extensively analyzed. Seven of the most useful of these reports and web pages were:

- *Understanding and Overcoming the Energy Mortgage Barrier: Financing Energy Improvements in Existing Homes* by Richard Faesy, 2000.
- *The HERS Rating Method and the Derivation of the Normalized Modified Loads Method* by P. Fairey, J. Tait, D. Goldstein, D. Tracey, M. Holtz, and R. Judkoff, 2000.
- *Report to the Board of Directors on Energy Rated Homes of Colorado*, by the Colorado Housing and Finance Authority, 1998.
- *Without a Facilitator*, by Federal Energy Teem, 2002.

- *RESNET Study of Successful ENERGY STAR Homes Programs in Targeted States for the Joint Management Committee*, by the Residential Energy Services Network, *2002.*

- *White Paper on Using Home Energy Ratings to Improve Energy Code Implementation*, by the Residential Energy Services Network, 2001.

- *RESNET Member News.*

Presentations at the annual conference of the Residential Energy Services Network that were available as power point presentations were analyzed. Seven presentations were used as data.

Nine mortgagee letters from the Department of Housing and Urban Development were used to determine the development of one of the most important energy efficient mortgages, the FHA EEM

There were also a substantial number of additional documents and web pages from the trade literature that were used for background information on the processes of residential construction, mortgage financing, and real estate sales. The most important are below.

- Builder 100 data from Builder Online

- Seven articles from Reality Times

- The Boulder Real Estate Services' Boulder County Home Buyer's Handbook

- ThinkGlink.com: Money and Real Estate News that you can use everyday

- A Home Buyer's Guide to the Closing Process in Northern Fairfield County, by Raymond P. Yamin, (2004)

- Twelve articles from Home Energy On-line

For additional background information and assessing the promotional work by HERS providers, seventy-one articles in major newspapers indexed on Lexis Nexus from 1986 to 2001 were analyzed.

Also, the web pages of trade associations and government bureaus were very useful for information on the various specialty firms in the residential housing industry. Their pages contained summaries of the roles of their trades in the housing industry and information on organizational size and structure.

- National Association of Independent Fee Appraisers

- National Association of Home Builders

- National Association of Realtors

- American Society of Home Inspectors
- Bureau of Labor Statistics
- Qualified Remodeler

Survey of HERS raters: A telephone survey was administered to a nation-wide population of HERS providers with the goal of assessing their basic organizational structure and capacities for system building. Specific questions were asked to identify day-to-day and month-to-month routines, the professional background of the staff, problems and successes that HERS providers were having including the number of ratings conducted, and their relationships with other organizations in the residential housing industry. See Appendix C for the questionnaire. In the fall of 2003, a telephone questionnaire was administered to a random, stratified, final sample of 17 HERS providers out of a nation-wide population of 63 HERS providers. The population was stratified into 23 first-generation HERS providers (mostly for-profits and government programs) and 46 second-generation HERS providers (mostly for-profit firms). The final, stratified sample consisted of 11 first-generation HERS providers and 6 second-generation HERS providers that were reached by phone and agreed to complete the questionnaire.

Interviews of EEM facilitators: In the spring of 2005, staff at firms that facilitate the completion of EEMs was interviewed to expand upon the data collected during the summer of 2000. The previously gathered data to which I am referring was collected about EEM facilitators at field locations in Mountain View, California and Burlington, Vermont through face-to-face interviews and obtrusive observation. Staff at three additional firms specializing in EEM facilitation was interviewed to collect data that mirrored most of the data gathered through field methods in the summer of 2000. An interview guide is in Appendix D and was structured to include questions about organizational structure and routines that could be used for system building, problems and solutions, and relationships with other organizations.

Part II

Chapter 3: An Organization-Based Theory of System Building

The social sciences already know a fair amount about large complex organizations. Indeed, complex organizations are one of the most extensively studied topics in sociology. However, we know relatively little about them as a driver of large-scale, social change. Charles Perrow (1991; 1997) and others have noticed this shortcoming and argued that we need to put large, complex organizations front and center in our theories of social change.

Some of the largest and best-studied organizations are corporations. As discussed, these are at the center of the technological and social infrastructure and are the drivers behind sociotechnical change. “The techniques of producing goods and services—technology—have no life” of their own “without corporations” (Perrow 1991, 726). Moreover “big, bureaucratic organizations are largely responsible for the direction” of sociotechnical change (Perrow 1997, 66).

> . . . the appearance of such organizations in the United States makes organizations the key phenomena of our time, and thus politics, social class, economics, technology, religion, the family, and even social psychology take on the character of dependent variables (Perrow 1991, 725).

Perrow is essentially arguing that large, complex organizations are the primary independent variable in modern society. Other social scientists have stated similar. Neil Fligstein and Robert Freeland suggest there is considerable agreement among the diverse social sciences that

> . . . the viability of the industrial enterprise is intimately linked to issues of governance [i.e., organizational structure]. . . as a problem of managing interdependence. To ensure that continued growth and profitability, owners and managers must make sure that organizational processes are preformed smoothly and predictably. Yet each entails interdependence between different actors within the corporation and between the corporation and the larger social world of which it is a part. Those seeking to govern the firm must gain control over the firm’s internal and external environments in order to manage and stabilize their interdependencies (1995, 22).

Furthermore, all of these authors recognize that the market success of new technologies usually depends on organizations having the capacities to build and maintain a well-integrated sociotechnical system to support that technology. David Teece, an economist, is rather specific when he attributes complex technological change to complex organizations.

> Innovation is characterized by technological interrelatedness between various subsystems . . . [and these subsystems] must be in close and continuous communication and engaged in mutual adaptation if innovation in commercial relevant products and processes is to have a chance of succeeding. . . . successful commercial innovation usually requires quick decision-making and close coupling and coordination among research, development, manufacturing, sales, and service. Put differently, organizational capacities must exist to enable these activities to occur with dispatch (Teece 1998a, 135-136).

Also, see Chandler (1962; 1977; 1990), Beniger (1986), Lazonick and West (1998), and Perrow (1991).

Despite these observations, there is little theory that links the characteristics of organizations to sociotechnical systems and to sociotechnical change. The work of a few authors such as Chandler (1962; 1977; 1990) and Fligstein (1995) helps explain the implications of organizational structure for control and coordination, and in turn the consequences for profit and organizational growth, but do not theorize about the relationship between organizations, technological change, and sociotechnical systems more broadly. Much of the rest of this chapter will be focused on constructing the basic elements of an organization-based theory of system building. However, before I begin that discussion, I will review the literature on sociotechnical systems, and then more broadly the literature on society and technology.

Literature on Sociotechnical Systems and Organizations

As mentioned, technical inventions largely succeed because they are supported by integrated, well-developed sociotechnical systems. The diverse social and technical parts are interconnected in the sense that the absence of, or change in, one will affect others. Thus, a system may not function well, if at all, without all its major components and the success of new devices will be determined by the extent it can be integrated into the existing system (Hughes 1989; Beniger 1986; Bijker, Hughes & Pinch 1987).

To exemplify how the mismatch between a technical invention and the existing sociotechnical system can hinder the adoption of that invention even when it is arguably economically, technically, and environmentally superior, consider the following hypothetical example. Imagine that you are purchasing a new home and want to install a solar water heater. After a frustrating few days trying to find a retailer to sell and install the solar appliance, you locate a business that is 80 miles away. Relatively pleased, you approach your loan officer with the hope of financing the solar water heater along with your house.

You tell your loan officer about its technical marvels and how much money that you will save on your utility bills. Your loan officer says, “Sorry, but you are maxed out on your loan to debt ratio. I cannot loan you any more.”

You explain that the money saved will offset your additional bank payments. “Perhaps” he says “but it’s not my area of expertise. My cousin bought one. When the pump broke down on the solar water heater, he had trouble finding anyone to service it because the installer had gone bankrupt.”

Then a nearby secretary says, “Solar water heaters? I looked at a house a few years ago that had one. The thing looked strange so I didn’t buy the property.” You and your loan officer start to think the same thing. In addition to the hassle of purchasing a solar water heater, it could end up being a liability.

Still attached to your idea, you say, “Yes, but a solar water heater will save money and make me a lower risk for a lender, and increase the value of my home.” Still nervous about lending money for such a technology, the loan officer asks, “Do you have any hard data?” At that point, you realize that your loan officer is not going to finance a solar water heater, and perhaps it is for the best.

You conclude that despite the many benefits of solar water heaters, the most rational decision is to stick with a conventional appliance. This is because the system has its own rationality that reinforces conventional technology and creates disadvantages for alternatives (Marcuse 1941). While this story is hypothetical, the problems in it have been frequently encountered by alternative technology advocates and researchers (Cowan 1996, 1990; Farhar, Collins & Walsh 1996; Farhar and Eckert 1993; Lutzenhiser 1992; National Renewable Energy Laboratories 1992) and in the author's field interviews.

Alternative technologies are, by definition, not supported by a well-developed sociotechnical system, which is a problem for those promoting them. Even though alternative technologies might be technically and economically feasible or even superior to conventional technologies, this is not enough for technologies to succeed in the market. As stated by Hughes (1989), the sociotechnical system as a whole is the primary determinant. In the above example, the system was missing retailers, repair workers, cultural aesthetics for alternatives, financing mechanisms, a real-estate market that recognizes energy savings, and institutional arrangements to assess the feasibility of alternative technologies. Quite predictably, a solar water heater is unlikely to work well within the existing system because the system is missing the parts that are needed for that alternative to be convenient or even feasible for most people to use.

Thus, for a new technical device to succeed it must either be compatible with the existing system or the existing system and/or device must be reshaped. For radical new technologies, it will usually be necessary to build an entire new set of system arrangements or radically restructure existing ones. For incremental innovations, small changes in the existing system may suffice, but even these can meet strong resistance from those with a vested interest in the existing system.

The concept of sociotechnical systems is a powerful way of describing relationships between the social and technical world that are not well captured by looking at society in isolated parts. One of these characteristics is a systems rationale that weaves together the parts of the sociotechnical system into a more smoothly functioning whole—a rationale that contains values, logics, and assumptions about what technologies are supposed to be used and which are not (Marcuse 1941). The above story explains how the choice of a conventional water heater over that of a solar hot water heater can be the most rational when viewed from a systems perspective, even though solar water heaters are arguably economically and technically more sound in many parts of the country. However, realistically, sociotechnical systems do not always have a single rationale that ties together its various components into a larger whole that functions smoothly and efficiently. Social actors typically have their own interests, different than those of others and different from any collective goals and rationalities that characterize the larger system. Because of this, it is a difficult collective behavior problem to build a system where individuals and organizations with diverse interests, beliefs, and values will cooperate with each other and yield a smoothly functioning system. Even for dominant rationalities, such as the pursuit of profit, it is seldom monolithic.

Complex organizations and their ability to internalize other organizations and the activities of other social actors is one of the most effective solutions to this collective behavior problem that system builders have found (Perrow 1997). Once internalized, corporate organizations integrate the parts of the system into their vertical and horizontal management structure that include lines of authority and communication to control and coordinate the new parts of the firm. Many decisions that were once made by individuals and small firms in the marketplace are now made within complex, bureaucratic, managerial hierarchies. As Chandler (1977) described, the overall historical trend has been for the "invisible hand" of the market to be replaced by the "visible hand of managers." Large-scale, corporate organizations have absorbed and rationalized much of the society around them (Perrow 1991).

The Literature on Society and Technology

Most social scientists who write about society and technology agree on a number of key things. There is a wide consensus that the technical world is inherently part of the social world and that the two evolve together. Pieces of technical hardware are integral parts of sociotechnical systems, and take on social significance through the way social actors intentionally or unintentionally use these pieces of hardware to influence each other and the rest of their social and biophysical world. Moreover, pieces of technical hardware play the role of intermediates through which social actors influence each other.

It is agreed that technical change is a socially determined, emergent, path dependent, contingent, multi-centered process. Diverse social groups continually struggle with each other over the direction of sociotechnical change and negotiate and renegotiate the structure of their relevant systems. The tentative end of these debates is reached when the relevant groups agree on definitions to technical problems and solutions. Whether a new technology is widely adopted and used depends on this process of negotiation and renegotiation and, of course, by the larger cultural, institutional, and organizational context.

These are very refreshing and relatively recent perspectives on the relationship of the technical and social world, compared to mainstream sociology that has ignored the technical world and compared to popular views of technical change that are simplistic, autonomous, and tautological. However, despite the contributions that these authors make to our understanding of the relationship of the social to the technical, most of the theories promoted by these authors have significant shortcomings.

I already discussed Thomas Hughes' concepts of sociotechnical systems. At least two additional scholarly bodies of work have attempted theories of system building. The second is the actor-network theory (ANT) approach of Law (1987), Latour (1988), Callon (1987), and Law and Callon (1992). Instead of writing specifically about a sociotechnical system, these authors use the concept of actor-networks that are seen as being made up of both social actors (i.e. people) and technical actors (e.g. machines and pieces of hardware). Technical and social actors are typically viewed on equal terms with each other—neither has more explanatory value than the other—and the literature has devised a neutral theoretical language to describe the interactions of these two types of actors in the network.

The third body of work is the social construction of technology (SCOT) framework that is advocated by Bijker and Pinch (1987) and Bijker (1993). They do not specifically refer to organizational structures on the shaping of the sociotechnical system, but instead focus their research on technical debates. To them the system is a set of meanings of technical problems and solutions where relevant social groups compete with each other to shape these meanings. For Bijker and Pinch, the system is mostly a set of "relevant groups" and socially constructed meanings.

These second and third theoretical approaches have shortcomings that make them inappropriate for the type of organization-based theory of system building that I have in mind. First, ANT has created a theoretical dead-end by relying on neutral language to describe the relationship between the social and technical world. Because of this particular way of not privileging either social or technical factors for explanation, ANT collapses the two levels of organization into the single level of the actor-network that poorly captures the unique characteristics of both the social and technical world. The robust explanatory value of the social world is largely lost, and the basic but powerful structuring influence of the physical/technical world has been mostly ignored.

Second, SCOT and ANT both describe the relationships among the technical, social, and economic parts of society as parts of a seamless web. These components are permanently associated with each other with no inherent distinctions, and these authors go so far as to suggest the futility of delineating among them. This creates a problem. Even though the social and technical world is interconnected, the literal use of the term "seamless web" undercuts the predictive and explanatory utility of SCOT and ANT. Social science is a study of relationships, and this requires analytical distinctions. Suggesting that the world is too seamless to make distinctions within it is dangerously close to abandoning social science.

Third, both SCOT and Latour of ANT tend to view the sociotechnical system as only a set of socially constructed meanings (Bijker and Pinch 1987) or rhetorical scripts (Latour 1988). While socially constructed meanings are an important part of sociotechnical systems, so are other components including pieces of technical hardware, organizations, and institutions, but these are mostly neglected.

There is a fourth problem to the SCOT and ANT approach. Because their frameworks give limited attention to organizational and institutional structures and sources of power, too much emphasis is placed on the agency of social actors, which are addressed as relevant social groups by Bijker and Pinch (1987) and heterogeneous engineers by Law (1987). Technological controversies are reduced to rhetorical free-for-alls among relevant groups whose definitions of situations are largely unrestrained by larger social structures. Also, there is little or no consideration given to sources of power in struggles over the direction of technological change. Winner (1993) and Thomas (1994) give a similar critique. Other authors have addressed these shortcomings, such as Shove (2003) who clearly links the role of nation-wide and even world-wide institutional and technological change to changes in the day-to-day routines that guide household pursuits for comfort, cleanliness, and convenience.

Fifth, and related to the fourth, the writings of all these authors are largely descriptive. Very little work has been done to develop and empirically verify a set of variables that can explain the direction, speed, and kind of technological change. Although the dynamics of organizations, institutions, and culture in the process of technological change are theorized and empirically examined, seldom have these authors attempted to discern and empirically validate the exact characteristics of these organizations, institutions, and culture that can predict the speed and direction of technological change. Consequently, the literature on society and technology has produced an understanding of the anatomy of technological change instead of an understanding of the root forces that drive technological change.

Hughes and Callon, and Shove as well, seem to have avoided more of these above problems than others. They have recognized the unique contributions of both the technical and social world to sociotechnical systems and that these systems cannot be adequately studied as merely a set of socially constructed meanings.

One interesting concept that has come out of the systems/actor-network literature has been that of "points of resistance" (Callon 1987), which Hughes called a "reverse salient" (1989). The weakest component of a sociotechnical system will hold back the entire system. For example, the development of an affordable, high-capacity, long use-life battery appears to be holding back the development of a system of electric cars. These authors note that points of resistance can come from anywhere in a system including pieces of technical hardware, organizations, institutions, and cultural components. Once system builders identify a "point of resistance" and then improve upon that component and integrate it with the rest of the system, the system will then develop forward and toward a greater ability to support the use and diffusion of the given technology. Of course, as soon as a point of resistance is removed, one or more other points of resistance will develop as the system moves forward.

While Callon identifies himself with ANT, his work is closer to Hughes in many ways, but there are important differences. Hughes, a historian, attributes a great deal of agency to individual system builders, such as Samuel Insull, to shape the direction of sociotechnical systems. His tendency to focus on the agency of individuals is likely due to his discipline's tendency to invoke great men's explanations of history. He focuses too much on these men's brilliant insights and neglects their mistakes. He also overemphasizes their influence and downplays what they cannot control. Likewise, Hughes neglects that the influence of these individuals came from their position in powerful organizations allied to other powerful organizations, and not just from their own skills. Without their organizations, they would not have changed history. Also, although Hughes acknowledges that change and stability can come from any part of a system, in practice he places considerably more emphasis on the technical parts of systems, and thus privileges it as an explanation for resistance and change in systems.

Callon appears more inclined to emphasize cultural, organizational, and institutional factors. However, he does not use the term "sociotechnical system," but instead refers to a heterogeneous network of social and technical actors embedded in a larger cultural, organizational, and institutional context. In doing so, he might unjustifiably privilege the heterogeneous network above the rest of the sociotechnical world.

Michael Mann (1986), from an entirely different body of work, offers advice. He suggests that when beginning an analysis, there is no *a priori* reason to assume that any part of a sociotechnical system is more important at explaining either change or stability. Change and resistance to change can come from any part of a system or from external sources. Thus, his work suggests that to explain technical change, researchers need to be able to cross over disciplinary boundaries and use a theoretical framework that is broad enough to include a diverse source of causal factors in a grounded analysis of data.

Despite their contributions, none of these theories do much to explain the causal process of change and of stability in a sociotechnical system with operationalized concepts that can be tested and that can be used to make predictions. I suggest that part of the problem has been a lack of attention to the structural characteristics of organizations within the social technical systems and how these organizational characteristics relate to change and stability in these systems. I will now focus on such characteristics and their relationship to sociotechnical change.

The 0rganization-Based Theory of System Building

In this study, organizations are theorized to control and coordinate the parts of sociotechnical systems as these systems change and develop. They construct new organizational parts for the system as needed, and then integrate those new parts into their management hierarchy or external networks. Such organizations also frequently shape the structure of new institutions or culture arrangements. Likewise, these organizations exert influence on other external parts of the system to shape and reshape its structure to support its core activities and technologies. I will theorize how organizations go about these system-building activities, but first I need to elaborate on exactly what I mean by a sociotechnical system.

As noted, sociotechnical systems consist of technical and social aspects. However, I will be giving more attention to the social parts rather than the technical parts. This is not because the social is inherently more important, but because social actors have agency and technical parts do not and thus the social parts of a system seem more useful for explaining sociotechnical change. I do agree with the society and technology literature that technical change is a socially determined, contingent, multi-centered process. Likewise, the technical parts of the system take on a social significance through the way social actors intentionally or unintentionally use pieces of technical hardware to influence other social and organizational actors and the rest of their social and physical/technical world. Moreover, pieces of technical hardware play the role of intermediates through which social actors influence each other, and the way that this occurs will partly depend on the physical properties of the technical hardware. In this way, technical components have a structuring effect on the system as a whole.

Also, it will sometimes be useful to refer to a *meta-system*—a larger set of societal arrangements that are external to a sociotechnical system. Setting boundaries for a sociotechnical system is always somewhat arbitrary and there are always additional organizations, economic and political institutions, and technologies that have at least some influence on the sociotechnical system being studied.

Routines are the fundamental building blocks of the social aspects of sociotechnical systems. A large portion of the theory will be built around this concept of routines, and data will be collected, organized, and analyzed according to it. A *routine* is defined as a series of interconnected, learned behaviors that are repeated by the same people, toward a specific goal, in the same context, and that are interconnected with other series of similar learned behaviors (adapted from Feldman and Pentland 2003). A routine has both a mentalistic side to it and observable behaviors that manifest from it. These are building blocks for the rest of the system in the sense that sets of routines can be engaged in more complex processes to achieve more complex goals. In turn, these sets of routines or processes are integrated together into organizations and their functional units (e.g. divisions, departments, offices). In other words, the manifested behaviors of routines constitute the basic day-to-day activities of organizations. Also, as discussed below, some routines provide integration between organizations in the network with each other. Likewise, as Giddens suggests, the mentalist aspects of routines provide for integration into larger social institutions (1979; 1984).

Another important concept is of course that of organizational capacities, which are used to build, shape and influence the sociotechnical system. For an organization to be considered an *organizational system builder*, it must 1) have at least some of all five organizational capacities for system building and 2) have intentionally used these capacities to reshape its relevant system with at least some success. The concept of participant-advocate is similar to that of an organizational system builder. As mentioned, participant-advocates are those who engage in the production, distribution, and/or selling of the alternative technologies that they promote. Although many participant-advocates are system builders, some are not. For example, a firm that has conducted and advocated for HERS ratings for the last ten years, but has neither tried to expand, innovate, nor help develop the HERS infrastructure has still been a participant-advocate. However, this firm has not been engaging in significant system building and thus is not a system builder. Also, whereas system builders are organizations by definition, the concept of participant-advocates can apply to individuals as well as organizations.

Once again, these five organizational capacities for system building are the:

- Capacity to collect, manage, and analyze information on the current state of the system

- Capacity to strategically evaluate the current system, plan new system arrangements, and conduct oversight of the implementation of strategic plans
- Capacity to control the various parts of a system
- Capacity to centrally coordinate various parts of a system
- Capacity to fund system-building activities including the internal organizational development of organizational capacities.

In theory, these capacities can be possessed by many different types of organizations whether private or governmental, non-profit or for-profit, or corporations, partnerships, or sole proprietorships.

These capacities and the routines that comprise them are not mutually exclusive of each other, and some presuppose the existence of other capacities. For example, all the capacities are dependent on the capacity to generate financial resources for system maintenance and building. Also, having the capacity to control parts of a system presupposes having information about those parts; likewise it is difficult to gain information about parts unless some control over them is possible. Moreover, the ability to coordinate parts of a system presupposes both information about, and control of those parts.

Some readers may wonder if control and coordination are the same. They are not. Control implies the ability to influence or shape a part of a system in a predictable fashion. Coordination implies the ability to keep two or more parts of a system in sync with each other, which is different from just controlling them. It implies a decision making unit capable of monitoring information flows from different parts of a system and control of those multiple parts to keep them in sync.

While the concept of organizational capacities is useful for higher level theorizing, these are rather vague, amorphous terms. In actuality, these capacities for system building can manifest into a variety of different internal organizational structures that are typically grouped by their function in relation to the larger system. These organizational structures include divisions, departments, and offices, organizational process, and sets of more specific routines. These concepts are often useful when gathering data about and discussing how system building occurs on a practical, day-to-day basis.

As just implied, organizations are usually not structured into subunits that focus specifically on information gathering, control, coordination, generating financial resources, and strategic planning and evaluation. Instead, organizations are typically structured into units that make functional, operational, or other organizational units, which include manufacturing, distributing, marketing, and also a head office. Each functional or operational unit usually has a set of routines to obtain information, control, and coordinate various parts of the system, and also to obtain financial resources and make strategic plans. For example, R&D departments are functional units that have the goal of controlling the direction and pace of technological change and contain specific routines for the collection of information, coordination, and often some to make strategic plans. Most of the capacities for strategic planning, evaluation, and oversight usually reside in the head office.

One of the most important aspects of system building is for organizations to create new social or technical parts for a developing sociotechnical system and then integrate those parts into the existing system. Those new parts are very frequently technical inventions.[20] However, it will be useful to also consider new ideas about social arrangements as new social inventions, which includes any new way to organize human behavior as a set of organizational routines, a new version of a management hierarchy, or new institutional arrangements such as policies, laws, rules, standards, and protocols.

Large, complex, centrally controlled organizations go hand-in-hand with large, complex, sociotechnical systems, and in theory, without such organizations we would not have many of the sociotechnical systems that are equated with modernity. These organizational capacities function to maintain existing systems arrangements, to fit new inventions into the system, and to directly control or exert influence over the overall direction and pace of sociotechnical change. In theory, the important parts of a large-scale, complex sociotechnical system will have a corresponding set of organizational capacities to control, coordinate, and keep them integrated with the larger system as it evolves.

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[20] A technical invention is defined as any conceptual idea of a technical nature regardless of its feasibility. This is essentially the same definition that the U.S. Office of Patents and Trademarks uses.

Having a full set of organizational capacities is more important for some system-building endeavors than others. One of these important situations is when a basic technical or social invention requires substantial modification to it and many different parts of the existing system in order for that invention to fit well within the system, and for the use of that invention to be reasonably supported by the system and widely used. These are *systematic* innovations as opposed to autonomous innovations (Teece 1998a; Chesbrough and Teece 1996). An example is the telephone. Before the telephone became a viable technology, an almost entirely new sociotechnical system had to be constructed of wires, relay systems, local exchanges, and supporting organizations and institutions. This is in contrast to innovations that can be introduced into a system with only a small number of minor changes in the rest of the system, which are referred to as *autonomous* innovations. For example, compact disk players were easily fit into car stereo systems along side cassette players without any modifications to stereo systems or cars.

Managerial Integration vs. Integration through Networks

To establish capacities for control, information and coordination, the two most useful approaches that organizations can take to system building are managerial integration and integration through networks. Managerial integration is primarily integration among vertical and horizontal management structures, and network integration refers to relationships between organizations that give an organization some access to the capacities of other organizations or influence over parts of these. In both instances routines provide integration through by structuring day-to-day inter and intra organizational activity.

The management hierarchy is a set of routines for planning, hiring, training, rewards, oversight, and firing (which by other names are routines for strategic planning, control, and obtaining information). Networks are not much different. Just as different parts of an organization are integrated through sets of routines, network arrangements between separate organizations are also integrated through routines for information, control, coordination, and the flow of financial resources. Integration occurs through networks (via routines) just as it occurs through management hierarchies.

However, I want to say more about what I mean by *integration*. When two or more organizational parts of a system (managerial units) are integrated, these organizational parts are characterized by the following. First, and most importantly, the proper execution of the routines for each managerial unit are dependent on the routines of the other managerial unit for information, orders, financial resources, services, inputs, et cetera. Also, the routines of each managerial unit are integrated in some or all of the additional ways. Second, individuals who carry out the routines for each managerial unit are familiar with the routines of the other unit(s). Third, the routines of each follow many of the same standards, conventions, units of measurement, and written policies. When parts of a system are highly integrated in this manner, the activities among them proceed so smoothly that their distinction as two managerial units is blurred.

When integration is between managerial units within the same organization, it is called managerial integration. When the integration is between two organizations, it is integration through a network. Regardless, it is the same basic phenomenon. *Networks are as much of an organizational phenomenon as are management hierarchies,* even though there are usually more interactions and interconnections within organizations than among organizations in a network. When the term "network" is used, it is to denote sets of organizational routines that integrate one or more organizations and their activities.

The important point is that the routines providing integration among organizations can also be used as *organizational capacities* for system building. In other words, organizations often network with each other to acquire the inputs they need and to access the R&D, marketing, public relations, and lobbying abilities that they need for system building and do not sufficiently have in-house. Thus, while capacities originate in the routines of an organization, these capacities extend (so to speak) through the network into other organizations. In this way, networks allow organizational system builders greater capacities for system building, such as through long or short-term contracts, joint ventures, and collaborations.

The more interrelated the routines of two organizations are, the greater the integration among them, and the greater the organizational capacities for information, control, and coordination that each organization has over the other through their network relations with each other. There is substantial variation in the degree of integration with networks. It can range from being on each other's listserv to that of cooperating in a hundred million dollar joint venture that has its own management hierarchy where information, money, materials, and services flow smoothly through the interconnected routines of each organization. However, it is usually assumed that networks provide less control, information, and coordination than does managerial integration (see Pisano et al. 1988a; 1988b for a similar discussion).

The main drawback to vertical and horizontal integration is that establishing managerial integration is typically more expensive, complex, and time-consuming than outsourcing. Managerial integration requires a substantial financial investment in human resources, technology, and organizational infrastructure that all must be carefully integrated into the larger organization (Pisano et al. 1988a; 1988b; Williamson 1975; Teece 1976).

Although network integration is cheaper and quicker to establish, it usually does not allow for as much control, information, and coordination. Also, some control and coordination can be lost over intellectual property, tactical knowledge, how labor is hired and trained for key tasks, and where investments are made. Furthermore, higher transaction costs might be incurred for some types of market transactions (Pisano et al. 1988; 1988b; Williamson 1975; Osegowitsch and Madhok 2003).

The above definitions of both networks and integration provide insight into why some networks fail to achieve the goals of participants and policy makers. If a network of system builders consists of organizations that have a serious deficiency in their in-house capacities for system building, the organizations will likely not have the capacities to be useful to each other. To the extent that they are able to establish routines that extend into the other organizations and provide for integration among a network, the additional capacities to which they gain access are not likely to give them much or any additional control, information, or coordination over the rest of the system.

Theoretically, without substantial in-house capacities or capacities indirectly acquired through a network with other organizations, system building can be very difficult if not impossible. This appears to be the case for organizations that do not have their own research and development capabilities. As described above, some innovations such as those that are systematic appear to require more capacities than others. Although solid data is not available, industry observers imply that when SMVRCOs enter joint R&D ventures or outsource R&D activities they usually or always do so to supplement their own extensive R&D capabilities. They never do so to replace of these capabilities (see Revilla et al. 2005; Pisano 1988a 1988b; Nakamura et al. 1996). As suggested by Pisano (1988a; 1988b), firms that have stronger in-house capabilities might be more able to "identify and internalize technology from outside sources." Furthermore, complimentary relationships have been shown between in-house and external R&D (Mowery 1982), and small manufacturers have been shown to be more likely to benefit from networks with external R&D laboratories if they have their own design capabilities (Bougrain and Haudeville 2002).

Government as a System Builder?

Government can have important structuring effects on the system-building process through various policy tools. These include government spending, tax codes, regulations, subsidies, and the legitimacy that it can use to intervene in a system-building effort. Also, it does have a large set of the organizational capacities that are usually associated with system builders. However, its ability to deploy these capacities and intentionally use them for system building is often highly questionable, and inconsistent with the premises of system building articulated above.

When government does intervene in a system building processes, its involvement is usually dominated by an overarching set of political routines, not routines for system building to actually bring about stated policy goals. Nevertheless, there are situations where it makes sense to consider the government as a system builder, and these will be discussed farther below.

The federal government usually has an extremely difficult time effectively deploying its capacities for strategic planning, control, and coordination as part of well-oiled system-building activities. There are several reasons. The federal government is extremely fragmented into different decision-making units, with separation of powers and checks and balances making it extremely difficult to coordinate and respond timely to problems and opportunities in constantly changing sociotechnical systems.

Particularly, when government action requires new legislation, a response from the state can take a decade or more, and it frequently does. Bills must be moved through sponsors, committees, and floor votes in both branches of Congress, and then signed into law by the executive branch. If funding is required, the entire political process must be repeated to authorize spending.

Even if signed into law, legislation can later be overturned by the judicial branch, and there are no guarantees that the administrative branch will fully follow the directives of the legislative branch. As mentioned by Fligstein (1990), the administrative branch is made up of many departments, agencies, and offices. Each of these have their own mission, interests, and constituency, and each has considerable discretion to drag its feet and not fully implement legislation, particularly when it comes to small details that are likely to escape congressional oversight.

Many legislative and administrative routines are heavily political in nature, and are *not* result-orientated toward actually bringing about the sociotechnical change that is the stated intention of the government action. These are political routines such as press briefings, hearings, and meetings with lobbyists, interest groups, and constituents that are heavily geared toward appeasing constituencies, building coalitions, and winning re-election within a few short years.

In sum, there are too many key decision-making points where government actions can be vetoed (Steinmo 1994) and too many political routines for politicians, bureaucrats, and interest groups to co-opt the government's organizational capacities for their own parochial interests. For the federal government to deploy its massive organizational capacities, each of its decision making units must line up, and do so quickly if a response is to be timely. More frequently than not, this is just impossible. While "elections," "separation of power" and "checks and balances" are good for democracy, they are counterproductive for effective system building.

However, there occasionally are instances where government has been effective in system building. One of these instances was the Manhattan project (Hughes 1989). Although more research is needed, it appears that government was directing a complex, system-building effort with unusual speed and effectiveness. Because the United States was at war, the government appears to have been able to suspend most of the democratic institutions, congressional oversight, and checks and balances. By doing so, a single government decision-making unit in the Department of Defense was able to consolidate control over the needed organizational capacities. However, such extreme situations seem to be rare.

Rationality and Isomorphic Change in the System Building Process

The organization-based theory of system building assumes that organizational system builders possess a degree of rationality. It assumes that, to a reasonable degree, organizations will collect information about the current state of the sociotechnical system, understand their options and consequences, rationally weigh the costs and benefits of each option, and then make an informed decision about how to use their organizational capacities to reshape the system. Although some of the examples already given and more in Chapters 4and 5 will support these assumptions to a degree, organizations never fully act this way. To the extent that they do, their rationality is always “bounded” in that it is constrained by a lack of information and imperfections in decision-making (March and Simon 1958). System building is not the only process that shapes changes in sociotechnical systems.

DiMaggio and Powell (1983) and Fligstein and Freeland (1995) suggest that there are non-rational processes at work. Specifically, they suggest that organizational decision-making is guided by institutional isomorphic change including striving for legitimacy, trying to mimic successful organizations, and/or group thinking among staff from the same professional backgrounds causes pressures toward conformity. These processes can occur regardless of evidence that an organizational structure or strategy is actually effective. Furthermore, it cannot be assumed that when organizations do make decisions, for example, to change their organizational structure that it will necessarily be more efficient and effective (DiMaggio and Powell 1983; Powell and DiMaggio 1991). Organizational restructuring and other decision-making can result in less efficiency and often even ruin (Fligstein 1990).

It is often difficult or impossible for organizations to choose the most effective organizational structures. Organizations seldom have accurate information about how their internal structures affect the larger sociotechnical system relative to other structural options, particularly during crises when objective information is not readily available and decisions need to be made quickly. Even in non-crisis situations, the system is often too complex and dynamic to make optimum decisions (DiMaggio and Powell 1983; Powell and DiMaggio 1991; Fligstein 1990). Particularly during these times of crisis and uncertainty, organizations will look toward others in their network for apparently successful solutions. Thus, organizational change becomes little more than educated guess work. Sociologists prefer to avoid words such as "efficient" or "optimal," and instead use terms like "effective" to describe organizational change. By "effective," it is simply meant that an organizational structure allows for organizational survival and perhaps some profit and growth (Fligstein 1995; Fligstein and Freeland 1995).

Additional Theory that is Needed

There are still many unanswered theoretical questions. How do organizational capacities actually manifest in real organizations? What manifestations are the most effective? Are all sociotechnical systems the same, or do some require more organizational capacities than others for system building, or perhaps different kinds of capacities? Also, theoretically, where does one draw the line between organizational capacities for system building, on one hand, and organizational structures that are used to run the operational details of an organization but that generate little or no change from year-to-year, on the other hand? What are the general characteristics of the system-building process? Chapters 4 and 5 will help us answer these questions by examining the well-researched, rich, historical details of the development of the modern SMVRCO and their related system-building activities.

Chapter 4: Early Corporations' Efforts to System Build

This chapter will describe how earlier inventors/entrepreneurs and their corporate organizations in the latter half of the 1800s and the very early 1900s created the necessary parts of their relevant sociotechnical systems to produce, distribute, and sell their new innovations. Creating these new parts of their relevant sociotechnical system was challenging. However, it was perhaps even more difficult to determine how to control and coordinate these parts and the efficient flow of inputs through process of mass produce, mass distribution, and selling their products to a mass market. For many early manufacturers, learning how to build the organizational capacities to control and coordinate the key parts of the system was crucial to successfully engaging in mass production, mass distribution, and selling to mass markets. When they succeeded, they were able to achieve unprecedented reductions in costs, economies of scale, higher profits, and accelerated organizational growth. It was quite common for early corporate organizations to spend decades rationalizing and re-rationalizing and also integrating and reintegrating the relationships among the parts of their relevant sociotechnical system to achieve these goals.

By studying these system-building activities, we will gain theoretical insights into the specific types of organizational structures that are possible for organizations to use as capacities for system building. It appears that much of this information will be generalizable to organizational forms other than large corporations, which will help build a general theory of system building that is useful to progressive advocates.

However, the historical data in this chapter suggests a problem. Most of the system building that was conducted through the very early 1900s was to stabilize particular sets of systems arrangements, such as to control the price and volume of goods that were sold by competitors or to control the flow of inputs through a firm. Organizational capacities were not used to dynamically control development of sociotechnical systems and the direction and pace of technological change. Because of that I will need to reconceptualize what I mean by organizational capacities.

This chapter also discovers shortcomings in the theory developed in Chapter 2 and potential problems in trying to empirically study changes in large-scale sociotechnical systems. From the work of Law and Callon (1992), Bijker and Pinch (1987), Thomas (1994) and others, we know that technological change is a dynamic, emergent, interpretive process that cannot be understood outside of the cultural, political, network, and historical context in which it occurs, and, thus, we should also suspect that system building is a similar process for the organizations that engage in it. This is exactly what this chapter suggests. The use and effectiveness of various organizational structures as capacities for system building cannot be understood outside of a broader context. Likewise, there also seems to be a set of recursive, non-linear dynamics that characterizes system building that affects the use and effectiveness of various organizational structures for system building. To examine the thesis in the latter chapters of this study, we need to better understand how this context and the larger dynamics of system building affect when and how various organizational structures are used as capacities for system building and to what effect.

I start this chapter by discussing how the transportation and communication infrastructure of the larger meta-system aided the system building of manufacturing firms. Actually, it was the organizational capacities of the railroad and telegraph firms that allowed the early transportation and communication infrastructure to function as well as it did to ship goods and convey information for early manufacturers. It has been previously demonstrated by Pacey (1990), Hughes (1989), and Buchanan (1992) that technological innovation often begets more innovation, but the first section of this chapter suggests that the more fundamental set of dynamics is that organizational capacities in one organization will beget new organizational capacities in additional organizations.

Changes the Metasystem Prompting Additional System Building

By the civil war, if not earlier, the United States had already begun its industrial revolution. Manufacturing firms were starting to use interchangeable parts, assembly lines, and other techniques of mass production. However, these techniques were still in a rather primitive form and were spreading very slowing through the economy. Technological change was still proceeding at a snail's pace by modern standards, and one of the barriers was access to mass markets. For many new technologies to truly be feasible and for these techniques of mass production to generate large economies of scale, they needed to be integrated with mass distribution to mass markets—all parts of emerging sociotechnical systems that needed to be assembled. In many industries, firms achieved this at the turn to the 20th century, although these firms engaged in mass production of only a single, undifferentiated product. It was not until firms diversified into multiple, differentiated products in many product lines during approximately the 1930s that mass production, mass distribution, and mass marketing became a defining characteristic of the U.S. society and economy in the form of a mass consumer culture, which will be discussed in Chapter 5.

Primarily the development of a quick, dependable, large-scale transportation system and to some degree an information system were important parts of an emerging meta system that made possible the efforts of entrepreneur/system builders such as Singer, McCormick, Swift, and Henry Ford and their respective corporate organizations. It allowed them to build their mass production and distribution systems and thus to access a mass market. These transportation and information systems were, of course, primarily the railroad and telegraphy. Prior to these, unless a firm was next to a navigable waterway, which allowed affordable transportation, it had little access to distant markets. In the 1800s of the United States, there was a growing but largely rural population within the vast interior of the country, and thus large, potential new markets. However, products could only be shipped by wagon or on the back of a mule to many of these rural areas.

Without access to mass markets, there was little incentive to invest in mass production or new products, and small organizations with very simple management structures usually sufficed to manage the production process. Prior to the 1900s, the primary unit of economic production was the family household that was mostly involved in agriculture and occasionally a cottage industry that produced a single product that it sold to local markets. The other business forms were a sole proprietorship or partnership of a small manufacturing firm or perhaps a store, tavern, etc. In all these cases, firms were small businesses, and with few exceptions they sold their products and services to a local market. The primary methods of control and coordination were patriarchal relations, direct oversight of all workers by owners, double entry bookkeeping, and handwritten correspondence. This "form of organization, and their methods of managing men, records, and investment" used by early 19th century American merchants "would have been almost immediately understood by the 15th century merchant of Venice" (Chandler 1977, 16), and "For centuries, business organizational forms, structures, and control methods in the Western World" underwent little change (Chandler 1992a, 263).

Chandler (1965) argued that one of the first, and the most important, developments that prompted the industrialization process and lead to more sophisticated forms of business organization were improvement to the transportation and communication infrastructure via the railroads and to a lesser degree the telegraph companies in the 1850s. Of course, there were additional barriers to technological change and industrialization in the 1800s in the United States than just a lack of transportation to ship goods to mass markets. However, transportation was a large one, and once addressed it directly and indirectly helped solve many of the other problems—some of which will be discussed below.

Improvements in transportation and communication infrastructure stimulated system building in at least two ways: first, the railroad and telegraph provided services that were much more complex and geographically disperse than previous lines of business, and thus presented significant management challenges to the railroad and telegraph companies. ". . . unless the movement of trains and the flow of goods were carefully monitored and coordinated, accidents occurred, lives were lost and goods moved slowly and with uncertainty . . . if railroads and telegraph enterprises were to achieve their promise of high volume, fast, scheduled flow of goods, services, and information" new organizational structures and forms of management were needed (Chandler 1992a, 264; Chandler 1965).

The small business model and Victorian styles of management were not feasible for these increasingly technical and complex lines of business. Confronted with the challenge of managing a business with unprecedented size, geographic scope, and complexity, the traditional small business model of direct oversight of all employees and relying on mostly family members as workers was impossible. Different management structures, tools, and routines were needed to control and coordinate the activities of each part of the organization. To address these needs, railroad and telegraph companies divided their organizations into units that represented the functional activities of their firms and geographic areas of the business, placed a middle manager in charge of each functional unit, and delegated enough authority to the head of each unit to successfully manage its functional activities. Top management coordinated these functional units based on the aggregate financial performance data of each unit.

Specifically, Chandler (1977) describes how the railroad companies were the first to use a three-tiered management structure with carefully crafted lines of authority and communication among the levels. Lower managers were responsible for 100 miles of track who then reported to middle managers who were responsible for 500 to 1000 miles of track, who in turn reported to the general manager and vice president. A board of directors set organizational policy. The staff in the central office was responsible for organization-wide issues that were vital for competitiveness, such as establishing protocols to move goods and passengers, quality control, and maintaining accounts. Also, the railroads invented a number of modern accounting techniques. Detailed information on operating, fixed, and variable costs and depreciation were used to decide where to make investments and the level to set prices (also see Ripley 1915, Johnson and Kaplan 1987).

Second, other firms developed complex forms of organization because of the effects that the railroads and telegraph companies and their associated technologies had on the larger economy. Small manufacturing firms and cottage industries found themselves in a new situation where large volumes of inputs could be delivered and their products shipped with unprecedented speed and dependability, and on relatively short notice for that period in history. This opened up mass markets, prompted the investment into and the development of mass production techniques to make enough goods to sell to those markets. This created entire new business possibilities and significant new economies of scale. However, when mass production and mass markets were pursued, it greatly increased the complexity of managing these firms. Under these opportunities and pressures, firms started to slowly adopt many of the organizational innovations that were being used by railroad and telegraph companies.

Some of the economies of scale that were achieved when investments were made into batch processes, assembly lines, and interchangeable parts were quite noticeable. Standard Oil Trust is a good example. The company decided to concentrate its refining of kerosene into three very large facilities and invested into batch production that produced 6,500 barrels per day. This reduced unit costs from 2.5 cents in 1880 to .45 cents in 1985, and similar examples could be given for foods stuffs, consumer durables, and other items (Chandler 1990; 1992b).

Once firms made an expensive investment into mass production facilities, it was financially crucial for them to maintain a continuous supply of high quality inputs and a market for their products. However, the supply of inputs was still quite undependable. To gain greater control over inputs and markets, many of the small, single unit manufacturers merged into a holding company and then further integrated with other firms both down stream and upstream into distribution and marketing (Chandler 1980). These businesses included steel, copper, and aluminum, refining; oil and sugar; processing grain and other agricultural products; canning and bottling; small machinery for agriculture and household appliances, and heavy machinery for industry (Chandler 1980; 1990; 1992b).

To control and coordinate the processes of mass production and mass distribution to reach mass markets was difficult, and it required new organizational structures and decision making. As noted above, mass production, mass distribution, and mass markets added greatly to the complexity, number of employees, and the speed at which inputs flowed into a firm and were made into products and delivered to customers. These were essentially the same management challenges that were earlier faced by railroads and telegraph companies, and the corporate manufacturers adopted many of the same organizational innovations either through imitation or independent problem solving. Middle management was established, and activities were organized into functional units such as purchasing, manufacturing, marketing, and financing and assigned to middle managers, which were in turn coordinated by a central office. Three-level management structures, vertical and horizontal integration, boards of directors, modern accounting practices, and the use of capital markets spread across the United States by WWI (Johnson and Kaplan 1987; Yates 1989).

Much of the evolving corporate management structure became codified by state legislatures when they gave statutory recognition to boards of directors, stockholders, and management as a requirement for specific kinds of corporate chapters. Furthermore, the Supreme Court decided in 1886 that corporations were separate legal entities with the same constitutional rights as individuals including rights in court, lobbying the government, freedom of speech, and holding property (Santa Clara County vs. Southern Pacific Railroad 1886) while being exempted from many of the liabilities and responsibilities of individuals. Accomplishing this social, legal, and political recognition and privilege was a tremendous win for corporate organizations. It has allowed "one or more individuals to leverage [potentially] massive economic and political resources behind clearly focused private agendas and to protect themselves from legal liability for public and consequences" (Korten 1995, 53).

The use of mass production and mass distribution to reach mass markets have been referred to as the second industrial revolution, and the new captains of industry that lead the system-building effort as the "new industrialists" (Chandler 1962; 1992b). A wave of associated technological invention and new products swept across the United States in the late 19th century in part due to the railroads' contribution to mass distribution (Chandler 1990; 1992b; Beniger 1986).

Intentionality and Rationality

Often when system builders are trying to introduce a radically new technology to the market place, the organizations, institutions, and other technologies that are needed for their specific technology to succeed do not exist in the relevant sociotechnical system. However, for individual entrepreneurs, the legally recognized, corporate organization with basic but relatively modern management techniques was an important tool for creating new organizational parts and integrating those parts into the rest of the emerging system arrangements. When they created new organizational parts, these corporate system builders faced a decision over how to integrate these new parts into the rest of the emerging system arrangements—either internalize them into the management hierarchy of an existing organization or establish network arrangements with them. In the rest of this chapter, we will review some of the efforts in the latter half of the 1800s to assemble supply-side parts of sociotechnical systems to manufacture, distribute, and sell new technologies, and these parts in turn became organizational capacities for generating revenue for future system building. Furthermore, the below examples suggest that one the most effective means that system builders have to control the parts of a sociotechnical system is to gain managerial control over these parts by internalizing them into a management hierarchy of an existing organization.

This discussion may at times give the impression that captains of industry engage in system building as a fully rational process and follow well thought-out master plans. Much of the time this was hardly so. Actually, it is helpful to view the assembling of the parts of sociotechnical systems from two perspectives. The *first* is the process of creating and assembling the missing parts of an emerging system that are needed for a technology to be affordable, readily available, and practical to use. Here it is reasonable to attribute some rationality to system builders. For example, the mid 19th century system arrangements for processing, distributing, and selling perishable food items did not have the technology to keep meats, vegetables, and fruit fresh or to even avoid spoiling while in transit. When a system builder noticed this problem and developed and financed refrigerated railroad cars and distribution centers, it seems reasonable to attribute at least some rationality to these efforts.

However, and second, there are other situations where rationality seems to play much less of a role, such as described by the concept of bounded rationality and by the theory of neo-institutionalism discussed in Chapter 2. When firms adopt new organizational structures it appears that often the most profound and lasting consequences for the sociotechnical system are unintended. It is only when these consequences are judged to be positive by firms that they develop these organizational structures for system building and intentionally use them to that effect. Examples of this will be discussed below in regard to the effects of anti-trust laws on corporate organizations and system building, and also the effects of increased organizational complexity on organizational structure. The actual cause-effect relationships involved in system building often stretch over decades and play out through second and third order effects that are probably beyond the abilities of either individual or organizational system builders to rationalize from the beginning and intentionally bring to fruition.

Creating and Integrating the Parts of Sociotechnical Systems

All three of the phenomena of mass production, mass distribution, and mass markets did not instantly come into being, of course. Each had to be built piece by piece and approximately in step with the other two. Although the transportation infrastructure was quickly being put into place, entrepreneurial system builders had to create additional parts of their relevant system in order to transport, wholesale, and retail their new products to a mass market.

Alfred Chandler argues that, when possible, manufacturers usually preferred to transport and sell their products to consumers through established shipping companies, wholesalers, and independent retailers when these were available. It was much cheaper than investing into their own distribution and sales infrastructure. Therefore, where retail outlets did not exist and the new industrialists could not afford to create them, they attempted to recruit franchised dealers or independent contractors to retail their products (Chandler 1992b). However, as we will see below, this was also often quite problematic.

In the latter half of the 1880s, railroads became capable of quickly delivering large volumes of many kinds of raw materials, parts, supplies and finished products to major urban areas and other parts of the country along rail lines. However, there were still problems. Even when suppliers and distributors were available and reasonably competent, "they were often unable to deliver on schedule and in the quality required by the new capital-intensive industries" (Chandler 1992b, 87).

The retailing situation also improved. In the late 1800s and early 1900s a number of large retailers emerged including Macy's, Lord and Taylor, Strawbridge & Clothier, John Wanamaker, Marshall Field, and Emporium (Teece 1993) which gave the new industrialists easier access to the mass market. Also, the mail order business of Sears and Roebuck and Montgomery Ward provided retailing services to previously isolated rural American via railroad and the US Postal Service (Borstin 1973; McGinty 1986).

However, the new industrialists were producing an increasing number of products that were specialized and/or highly technical in nature for the era, and most of the existing distributors, retailers, and consumers did not have the ability or technical know-how to transport, sell, service, and use them. For example, many products needed specialized shipping containers including bulk quantities of petroleum, vegetable oil, and perishable foods (Lloyd 1996; Goodwin, et al. 2002; Yeager 1981). Also, an increasing number of products were highly technical for the era that needed a well-trained sales and support staff that simply was not available at most retail outlets. Such products included industrial and agricultural chemicals, heavy and light machinery, and consumer products such as automobiles, sewing machines, and office equipment. Likewise, for many such products, the potential consumer had little idea about the benefits of these and how to use them. There was not a market that was waiting for the goods. Instead, that market had to be created by these system builders. Part of the problem was that the country had yet to develop a class of technically well-educated individuals to both sell and use these new products (Chandler 1990, 1992b).

These problems of mass distribution and mass markets presented a serious threat to the market success of new innovations, and had to be solved before many new products would be economically feasible to make sell through larger economies of scale. The most innovative of the new industrialists addressed these problems by taking steps to build mass distribution facilities and create a mass market. They did so acquiring or building the necessary organizational structures and technology for purchasing or manufacturing inputs and for distributing, selling, and providing customer service.

The new industrialists responded by creating new organizational and technological parts to expand and elaborate the existing transportation, wholesale, and retail infrastructure. When they did so, they had the choice of either integrating these new parts into their management hierarchy, or establishing these new parts either as subsidiaries, franchises, dealerships, or completely independent organizations and then forming network relationships with them. It appears that incorporating them into their management hierarchy usually resulted in superior organizational capacities for control and coordination, as will be discussed below. However, internalizing these parts of the system into their management hierarchy was usually too expensive, and many of these system builders had to make use of network relationships with these new parts of the system.

Different products needed different types of systems arrangements for distribution and selling. One way to compare the different demands that new products placed on system building is the extent to which a new product requires systematic innovation, and, also, how loosely or tightly coupled the relevant systems arrangements were. Systematic innovations have already been defined, but loosely and tightly coupled are new terms. If a system is *tightly coupled*, it is made up of technical and social components that must be well-integrated with each other and integrated in specific ways if the system is to support the use of particular technologies. In other words, for a tightly-coupled system there are relatively few ways that the system can be structured and still function or even function at all. Also, most of the parts of the system are important, if not vital, for system performance. A good example of a tightly coupled system is the telephone system that must include wires, transformers, switches, relays, and other electrical, mechanical, and also many social parts if the telephone, a core technology of the system, is to function. Most of these technical parts must be perfectly fit together using the same voltages, currents, and frequencies, and must be manufactured according to the same standards. This is in contrast to *loosely coupled* systems where integration among its various components can be weak, integration can occur in more than one way, and often many components are optional (see Perrow 1977 for a discussion of tight and loose coupling in a different context). In the text that directly follows I will compare a mildly systematic innovation in a rather loosely coupled set of systems arrangements with that of three different moderately systematic innovations in three rather loosely coupled systems arrangements. The mildly systematic innovation was refrigerated foods that could be shipped long distances. Two moderate systematic innovations were sewing machines and mechanical harvesters, and automobiles are considered here as a highly systematic innovation. The commonality among the last three is that these were "mechanically complex and expensive machinery [delivered] directly to consumers." The companies that sold these new products "required a network of dealers with knowledgeable sales staffs, the capability to provide financing to customers, and the capability to provide substantial services to customers after the initial sale was made." While the basic parts of the system were relatively straight forward, these system builders had a difficult time trying to rationalize the best way to integrate these parts with the rest of the developing sociotechnical systems (O'Brien 1997, 198).

Fresh Foods for Mass markets: a Mildly Systematic Innovation in a Loosely Coupled System

One excellent example of a mildly autonomous innovation in a rather loosely coupled system is the efforts of New England wholesale butcher, Gustavus Swift, who created and vertically integrated a set of organizational and technical components for a distribution and wholesaling infrastructure. After the civil war, the firm of G.F. Swift & Company noticed that major urban areas in the East were demanding more meat than could be produced locally and that great herds of cattle were grazing on the western plains. The main problems were that transporting live cattle long distances by rail was expensive and raw meat spoiled before it reached urban markets. There were moderate volumes of live cattle that were shipped by railroads over moderate distances to wholesale butchers in local markets. Although this was at great expense to the consumer, the proprietors of the existing system arrangements were quite content with the status quo and resisted. The railroad companies were heavily invested into facilities for live shipments and were reluctant to make new investments into refrigeration facilities for dressed beef (Yeager 1970; Chandler, 1962; Fields 2003).

To expand his market, Swift & Company had no choice but for his own firm to create the parts for a transportation and wholesale distribution infrastructure himself, which had to include some type of refrigeration, and then integrate these parts into the larger system. After experimenting with ice blocks, Swift & Company took advantage of the new technology of mechanical refrigeration in the late 1870s. The company designed and purchased a fleet of refrigerated railroad cars, and placed refrigerated warehouses in each major U.S. city as well as distributing, marketing, and retailing organizations that were managed by branch offices. It simultaneously invested in large scale slaughtering facilities, and diversified into other meats and dairy products. Swift & Company had built a new sociotechnical system for the large-scale production, distribution, and wholesaling of fresh meat and dairy, which were previously impossible to mass market (Yeager 1970; Chandler, 1962).

Swift & Company did encounter resistance from some consumers and industry participants. Consumers had a cultural prejudice against meat from cattle that was killed weeks ago and thousands of miles away, which had to be overcome through advertising. Also, local butchers organized the National

Butchers Protective Association to prevent the sale of western meat in Eastern markets, and convinced some railroad companies who were invested in live cattle distribution to boycott his refrigeration cars. The company overcame both problems through political and economic battles that ensued (Fields 2003).

By the end of 1890 this corporate organization had created “a huge vertically integrated industrial empire.” The company likely chose vertical integration to control the new parts of the system because it was probably the only way it could ensure the presence of both refrigerated distribution and retail outlets in each major city when many participants in the existing system were hostile to his business. However, vertical integration into at least retailing does not seem to have been necessary to control retailers in other ways. Swift & Company eventually sold off these facilities and began selling his agricultural products to independents that had their own refrigeration. Other meatpackers and companies that wholesaled fresh fruits and vegetables adopted a similar strategy (Chandler 1962, 26; Yeager 1970).

Refrigerated agricultural produce was only *moderately systematic* as an innovation. Only a few changes in the relevant system were necessary for refrigerated foods to be sold to a mass market. The most important was that of large-scale purchasing and butchering facilities, refrigerated railroad cars, large refrigerated storage facilitates in urban areas, and additional operating units within its vertically integrated hierarchy to manage these parts. Demand already existed, and only needed to be adjusted with advertising about safety and freshness. Political opposition existed but was fragmented and not extremely strong. Likewise, the parts of the system that needed to be changed were parts that were rather loosely coupled with the rest of the system. Firms that controlled the existing transportation and wholesaling infrastructure in the country were resistant of Swift’s efforts, and thus it really did not have any choice but to pay the expense of creating and managing the mass purchasing, butchering, transportation, and wholesaling faculties. The management hierarchy of Swift was crucial to controlling the flow of investment capital to these new parts of the sociotechnical system. However, Swift & Company never had to integrate into retailing.

Sewing Machines: a Moderately Systematic Innovation in a Loosely Coupled System

Isaac Singer invented the first truly workable sewing machine that was also a tremendous labor saving device for seamstresses. In 1851 he formed the Singer Manufacturing Company in Boston. For a considerable time, Isaac Singer struggled to find a way to nationally market his useful machine. There was a strong demand for his product, but he continually struggled with finding and/or creating retail and service outlets. His sewing machine was technically complex for the time and required well-trained sales and service staff in an era when most of the lay public did not have the technical background. Moreover, he and assistants could not "reach out personally and nationally to resolve the confusions of purchasers or the doubts of possible buyers." That type of small business model was impractical. Somehow he needed to put sales and service staff in the field, but a small business model was not feasible for the geographic scope (Scranton 1994, 650), and setting up retail outlets with well trained service and sales staff to be owned and managed by Singer Manufacturing was prohibitively expensive for his new company. His organizational solution was as novel for the times as was his invention. Singer built one of the first sophisticated dealer networks of independent businessmen. Although it was a constant source of problems, it worked well enough for him to stay in business (O'Brien 1997). Establishing a managerial hierarchy over that of retail outlets was probably the only thing that could have provided the control over retailing, service, and repairs that Singer needed, but it was too expensive.

Thus, Singer decided to develop a dealership network. His first attempt was to sell his machines to established retailers through existing wholesaler channels. His independent wholesalers were given exclusive territorial rights and the responsibility for supplying credit to customers. However, principal-agent problems made this unworkable. The wholesalers, who received only a small fraction of profits, did not aggressively sell his sewing machines. Also, the customers needed more instruction and post-sale support to operate the novel, relatively complicated machines than wholesalers and retailers were willing or able to attempt (O'Brien 1997; Dicke 1992).

After buying back the territorial rights from his wholesalers, his second attempt at retailing was to use a network of independent agents to run retail outlets that sold only Singer machines and received a 25%

commission. However, his agents tended to focus on the short-run commission and neglected instruction and service to customers, which was to the long-term detriment of his company. He abandoned this approach as well (O'Brien 1997; Dicke 1992).

He made his third and final attempt. It was the expensive option that he had been trying to avoid—company ownership and management a string of retail outlets to sell his sewing machines. After investing in such outlets, in 1885 the Singer Manufacturing Company hired traveling examiners to check on accounting and the uniformity of service. In 1893 it instituted installment payments to help customers finance purchases, and also a better compensation system for salesmen (O'Brien 1997; Dicke 1992).

Singer's sewing machine was a moderate systematic innovation in terms of its relationship with the demand side of the system. It was more systematic than refrigerated foods, in that system arrangements had to be set up to provide potential buyers with accurate information during the sales process, and mechanisms to provide service and repair, and also to provide consumer credit. To control these system arrangements that integrated directly with the demand side of the system, Singer Manufacturing Company was forced to eventually purchase and manage retail outlets. Swift never had to do so.

Mechanical Harvester: A Mildly Systematic Innovation in a Loosely Coupled System

The McCormick Harvester invented in 1876 was a horse-drawn machine that performed all the tasks that earlier machines had done separately, which included reaping, raking, and bundling stalks of wheat and other grains. The McCormick Harvesting Machine Company had been founded in 1847 to sell an earlier machined that only reaped grain, and it soon encountered problems similar to that of the Singer Manufacturing Company. It also was having a difficult time finding dealers to sell, service, and repair its machines. It started out by recruiting operators of general stores or other businesses to retail his harvesters, and provided written instruction on how to repair and service his machines that frequently broke down. However, these independent dealers largely declined to service and repair the mechanical harvesters, and the volume of complaints indicated to him that he needed a more sophisticated distribution and sales network (O'Brien 1997).

He then hired 40 to 50 well-trained, traveling, general agents to supervise and train the local agents to demonstrate and service the harvesters, and starting in the 1880s, company headquarters dispatched a "core of field agents" during harvest season to set up newly purchased harvesters and provide repairs. McCormick also developed the use of extensive advertising and installment credit (Olmstead 1995). This system seemed to work fairly well, and McCormick avoided the large expense of having to set up company owned and managed retail outlets that the Singer Manufacturing Company had to incur. He did so "by taking responsibility for demonstrating, maintaining, and repairing machines out of the hands" of his independent dealers over which he had much less control. This allowed McCormick "directly to ensure that customers would receive knowledgeable instruction in the operation of the machines and that the machines would be competently repaired" (O'Brien 1997).

The problems that McCormick had were very similar to that of Singer. Although the McCormick Harvesting Machine Company was eventually able to satisfactorily use its network relationships with franchised dealerships to retail his mechanical harvesters, it was only able to do so because it employed the network of traveling sales, service, and repair staff to provide a great deal of customer support to directly aid his dealers. Singer eventually had to invest in the company's own retail outlets, and Ford continued to have serious problems with its dealership network.

Automobiles: Highly Systematic Innovations in Both a Loosely and Tightly Coupled System

The problems that the Ford Motor Company had with the distribution and sales of its autos as an expensive, technically complex product were similar to those experienced by Singer and McCormick. There were differences, however, at least in degree. The auto was a highly systematic innovation, and some parts of the emerging sociotechnical system that needed to be integrated with this were tightly coupled and others were loose. Where the emerging sociotechnical system was loosely coupled, it sufficed for small, local, and/or decentralized organizations to engage in the system building.

About the product, "horseless carriages" were much more expensive, arguably more novel, and technically complex than either sewing machines or mechanical harvesters, and definitely more than refrigerated foods. Even the early autos were rather complex and expensive technological innovations composed of relatively sophisticated mechanical and electrical parts and chemical components. Model Ts sold for about $500 in 1913,[21] which were significantly more expensive than Singer's sewing machines that had sold for $30 in the 1870s through early 1900s (see Bissell 1999 regarding consumer financing). Nor was there anything really comparable to it that was readily available to consumers previously to its mass production and marketing. It was a truly novel product.

These characteristics made the early autos a highly systematic innovation. For these to be easily and widely used as they were intended, many different aspects of the basic invention had to be integrated into many different parts of the emerging sociotechnical system that would be the automobile-dominated surface transportation system. This system-building endeavor required that many new parts of the system be built. For consumers to easily use these autos, they needed consumer financing, places to buy fuel, service and repair shops, and sources of spare parts, roads, traffic laws, and places to eat and sleep while traveling long distances. However, there were probably close to an equal number of parts from the existing surface transportation system and other systems that were adopted or adapted for use in this new emerging sociotechnical system.

Ford Motor Company of the early 1900s is primarily known for its engineering and manufacturing prowess. However, the organizations accomplishments as a systems builder extend to other areas. After a short trial and error process, Ford was the first to design an "effective plan for producing a low cost, fairly reliable automobile in high volume and distribute it directly to customers" (O'Brien 1997, 195). In other words, Ford combined mass production with mass distribution to reach mass markets. He was quite probably the first to do so for an innovation as technically complex and expensive as the automobile. By the end of the 1800s, there were 100s of small automobile manufacturers. By the second decade of the 1900s, the Ford Motor Company had obtained the lion's share of the growing market by selling affordable cars to the growing US middle class.

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[21] The Model T sold for $850 in 1908, for $500 to $550 in 1913, and for $290 to $310 in 1926 depending on the accessories (Federal Trade Commission 1939).

His early success at mass production from interchangeable parts and a moving assembly line captured unprecedented economies of scale in the auto industry. Interchangeable parts had been in use since the civil war, but it was not until the 20th century that machine tool technology could produce the low tolerances needed for complex machines, such as in sewing machines and internal combustion engines. These mass production technologies required large initial investments, but yielded large cost savings when manufacturing was done in volume (McIntyre 2000).

> The main building on the sixty acre Highland Park site had four stories and measured 865 feet long and 75 feet wide, giving it nearly 260,000 square feet—and making it the largest building in the state of Michigan . . . The plant overwhelmed visitors with the constant motion and dizzying pace of conveyors, slides, and rollways and the final assembly line where workers completed a Model T every forty seconds. Henry Ford observed, "Every piece of work in the shop moves." Ford invested $2.8 million in nearly 15,000 specialized machine tools used by almost 13,000 workers who produced more than 230,000 Model Ts at Highland Park in 1914 (McIntyre 2000).

Ford was able to borrow somewhat from the mass distribution techniques of Singer and McCormick, but eventually went beyond them. In the beginning, Ford and other automobile companies made use of existing retail networks by either selling or consigning their autos to general stores in rural areas and department stores in urban areas. However, just as it was a problem for Singer, this did not allow for autos to be competently demonstrated and serviced and for adequate stocks of parts to be maintained. Retailers were too likely to treat automobiles as just another product in their store. Ford and other auto manufacturers had to develop a much more sophisticated set of systems arrangements within the relevant sociotechnical system to demonstrate, service, and finance personal automobiles (O’Brien 1997).

Ford embarked on the “path blazed by Singer and turned to the use of franchise dealers” that only sold automobiles and that were bought only from the Ford Motor Company, and numerous other automobile manufacturers used a similar strategy. The company had nine branch-manufacturing offices in 1909 and thirty-four in 1921 that recruited and supervised franchise dealers. There were nearly 7,000 of these dealers by early 1913. Although they were independently owned businesses, their franchise agreement with Ford gave considerable control to Ford headquarters over how selling, servicing, and financing were conducted. Ford was able to demand those arrangements because it had a lucrative product that dealers wanted to be able to sell (O'Brien 1997; Marx 1985; Hugill 1982).

Automobile repair presented a major problem when commercial auto sales began for the industry in 1896. Without repair shops to assist broken-down motorists, drivers carried their own tools, parts, and fuel, and conducted their own repairs. Independent repair shops emerged rather quickly at the beginning of the 1900s. However, because of a few hundred different manufacturers that often did not use interchangeable parts, access to replacement parts was extremely problematic before 1910. To the extent they were able, mechanics improvised, modified, and fabricated the needed parts for whatever models came upon their shop. "Early automobiles needed frequent minor adjustments and repairs as well as annual overhauling . . . [costing] as much as five hundred dollars per year," which was about as much as a car was worth (McIntyre 2000, 274; Barker 1985).

It was relatively easy for entrepreneurs to enter the trade of auto repair because little capital investment was needed, and soon there were an abundant number of shops in much of the country. However, there was still a serious shortage of honest, competent, well-trained mechanics with the proper tools and parts, and many auto owners complained of rampant dishonesty and inflated charges. These problems were not limited to Ford dealers. In the 1920s, a survey by the Illinois Automobile Trade Association found that the most commonly cited reason for not buying a second automobile from a dealer was unsatisfactory repair service. Ford executives feared that the expensive and poor quality repairs by dealers would damage the reputation of the model T and decrease sales (McIntyre 2000).

Taking these problems very seriously, in 1913 Ford began a major effort to rationalize the repair work at dealerships that used time-motion studies of repair work. Similar techniques had served the company well in the manufacturing process, and it thought these could be applied to repair work. Between 1915 and 1925, through a set of recommendations and requirements, Ford attempted to introduce labor saving tools and machines into the dealer repair shop, extensive specialization, mandatory flat rates for each type of repair, division of labor among mechanics, piece-rate wages for mechanics, and a rationalized shop layout. Ford was the first in the industry to attempt this, but by the 1920s other companies followed (McIntyre 2000; Dicke 1992).

While the larger dealer franchise often embraced these rationalized procedures, small franchises and independents often protested considerably. They insisted on their right and need to define the best way to repair cars because they had “limited capital, highly varied repair tasks, and an irregular flow of work.” They insisted that no two jobs were the same and many problems were not in the manual (McIntyre 2000, 296; Dicke 1992). Although the evidence is weak, implementation of these rationalizations appears to have been correlated with a reduced number of customer complaints (McIntyre 2000).

To the extent that the Ford Motor Company was reasonably successful at controlling and coordinating his distribution and sales network, it appears to have been primarily because of the high demand for model Ts that it created. Owning a Ford dealership was fairly lucrative. This allowed the Ford Motor Company to demand compliance with its policies if wholesalers were to remain Ford dealers (McIntyre 2000; Dicke 1992).

The systems arrangements that Ford set up to finance the manufacturing, wholesale purchases, and resale purchases of automobiles were crucial if the emerging sociotechnical system of the automobile-centered surface transportation system was to continue to expand and prosper. The Ford Motor Company, dealers, and retail consumers all lacked investment capital. At the beginning, the existing lenders did not want to take a risk on the automobile industry that was still in its infancy, and the industry had to set up their own financing mechanisms for its manufacturers, dealers, and retail customers. Because neither the dealers nor Ford and the other auto manufacturers could afford to finance retail customers, the dealers wrote installment contracts and sold them to independent auto finance companies. The auto manufacturers themselves set up the first of these finance companies between 1913 and 1919. Almost two-thirds of new cars and half of used cars were purchased with credit by 1920. Nearly 15,000 of these auto finance companies existed by 1925, and approximately 90% of the early auto financing was through factory-tied finance companies. However, Ford Motor Company was not the only, nor the first, auto manufacturer to use these factory-tied finance companies (Olney 1989).

So far I have discussed the centralized system-building efforts of Ford and other auto manufacturers. However, without direct assistance from auto manufacturers, many parts of the system were assembled and integrated by other organizations in a decentralized effort, as discussed below. Many of these efforts were by small, local organizations on the demand-side of the sociotechnical system. The most indirect influence that Ford and other auto manufacturers had on this decentralized system building was probably their success at producing relatively user friendly and affordable autos. The quickly growing popularity of automobiles created strong incentives and many opportunities for firms in related industries, government organizations, and non-profits to develop new technologies and services that catered to the autos and to engage in their own system-building at the local or national level. These included better fuels, antifreezes, oils, automobile accessories, and repair equipment. Likewise, politicians took the opportunity to please their constituents with better roads, traffic lights, and bridges. In the process, the automobile-based surface transportation system took on a life of its own and did so without automobile manufacturers being directly involved.

The petroleum industry is a specific example, which had already had some market success at making and selling kerosene and other fuels and chemicals. Many early autos used kerosene as fuel. However, the development of gasoline as a superior fuel resulted in an extremely important new source of revenue for them. Originally there were no specialized retail outlets to purchase gasoline, and it was only available through the auto manufacturers, sometimes in cans from hotels and bicycle shops, and also in cans from auto repair shops as they sprang up. Service stations with underground tanks fitted with hand pumps did not made their début until around WWI (Tucker 1993; Barker 1985; Corley 1992).

Neither are automobiles much good without roads and road maps to navigate on them. Initially, autos used the same roads/paths traveled by horses, bicycles, and foot traffic, but particularly in rural areas these were in notoriously poor shape, most not maintained, and often seasonally unusable. Motor clubs and auto industry trade associations soon formed and lobbied the federal and state governments to build and maintain road systems more suitable for auto traffic. The effort had a name—the “good roads movement"—and was codified with passage of the Good Roads Act of 1916, and firms emerged that specialized in road construction. The backward linkages from road building firms to other firms helped to stimulate development in other industries including those that were a source of asphalt, gravel, and cement, and that built bridges (Barker 1985; Goddard 1997; Yagoda 1988; Hugill 1979; Sutter 1995; Pace 1990). Restaurants, auto camps, motels, and other road side services for motorists sprung up as Americans took to the open highway in the 1920s and 30s (Belasco 1979; Sculle 1999; Dispenza 1995).

Management Hierarchies for Control and Coordination

When the system builders created the parts of the systems that were needed to support their inventions and new products, they also made first attempts to integrate these new parts with the rest of the sociotechnical system. They did so through integration of these organizational parts into the management hierarchy of their organization, into holding companies as subsidiaries, or through network relationships as independent organizations. Especially the small, young, capital-starved organizations preferred to integrate these organizational parts through network relationships because it was more affordable.

However, particularly with network relationships, these initial attempts at integration did not allow for sufficient capacities for control and coordination over these parts. A crisis of control would often emerge and the system builders would then re-rationalize how to better restructure and reintegrate the parts of the system. Sometimes they chose to merely restructure network relationships to increase their control somewhat, such as was the case with the McCormick Harvester, and it sometimes sufficed. Other times no network relationship could be found for sufficient control, and they chose to vertically and/or horizontally integrate the relevant parts of the sociotechnical system into single management hierarchies. This appears to have resulted in very effective capacities for control but often at a high cost of investment capital. This is what Singer Manufacturing finally did.

In the latter half of the 1800s and then again in the very early 1900s, there was a collective phenomenon where large numbers of corporate organizations re-rationalized and re-integrated their subsidiaries and also independent organizations into single legal entities and management hierarchies.

Corporate system builders reintegrated parts of their organization and larger sociotechnical system to gain better control over the parts and sometimes to more efficiently allocate their capital investments.

However, in each of these periods of reintegration and in subsequent periods, corporate system builders held a different set of beliefs as to what constituted organizational capacities and what changes in the system could be expected from a particular set of capacities. Organizational capacities and their use have been contextual to the particular stage of organizational development in an industry, political and economic forces, paradigms with the business world, and the larger world view of society. Each period of reorganization was also characterized by a different set of beliefs about how a corporate organization should pursue profit and growth.

Some of the theory in Chapter 2 was too simplistic to capture some of the important nuances of these system-building efforts. When corporate system builders did develop organizational capacities via their new management hierarchies in the latter 1800s and very early 1900s, these were capacities primarily for maintaining the existing sociotechnical system. They were not particularly useful for system building in the modern sense—controlling the pace and direction of sociotechnical change by continually introducing new technology and building new system arrangements. Nor did they start to develop these specific capacities for system building until the 1920s, which is discussed in Chapter 5.

At the turn of the century, corporate system builders were attempting to increase profit through vertical and horizontal integration to increase the efficiency of the flow of inputs into their firm and conversion into outputs. However, even before then, one of the first widely held business paradigms for increasing profit was the use of predatory trade—the disruption and destruction of a firm's competition by devious and sometimes illegal means. In the latter half of the 1800s, predatory trade considered essentially making and increasing profit. However, because most everyone used it, it was a strategy of mutual destruction. Many captains of industry recognized the ruinous nature of the situation, and decried predatory trade while simultaneously using it. They saw no other option but to be predatory, or else be preyed upon by another firm. For the firms involved, it was a crisis of control over competition.

First Crisis of Control: Defending against Predatory Trade and the State

During the later half the 1800s, the structure of most industries was a random assortment of firms that specialized in a single functional activity such as manufacturing, purchasing, wholesaling, retailing, and generating technological inventions, as discussed above. Some manufacturers did their own purchasing, and some their own wholesaling, but neither was the norm. Also, most firms that made products were either cottage industries or small manufacturers that sold to local markets and specialized in a single product that they made in one design that stayed the same year after year. Firms had very little control over other organizational parts of their relevant sociotechnical system, which was because of the very limited organizational integration and also poor integration due to network relationships of the relatively poor communication, transportation, legal, and normative infrastructure.

If firms wanted to increase their profit, they usually engaged in predatory trade against their competition—not through greater efficiency, R&D, or marketing that were uncommon concepts for the era. Predatory trade took the ruinous form of price wars, sabotage, hostile takeovers, and through many devious methods making it difficult for competitors to obtain inputs or have a market to sell their goods. These small manufacturing firms were specifically trying to control the demand for their goods and the price they received by ruining their competition (Fligstein 1990). Price and demand was a large concern, because the era experienced three periods of overproduction that led to major economic downturns—from 1873 to 1877, from 1885 to 1887, and the most severe from 1893 to 1897 (Hoffman 1970, 4). Especially during economic down turns, firms would compete for sagging market share by engaging in vicious trade practices against each other that tended toward mutual destruction. Confronted with both overextended manufacturing capabilities and predatory trade, many firms went bankrupt (Fligstein 1990).

During the late 1880s there were few government regulations and norms in the business community to stabilize price and supply and to minimize predatory trade. If they managed to drive their competitor into bankruptcy before similar happened to themselves, they would sometimes buy their competitors out (Fligstein 1990).

However, from the mid-1870s onward, a new business paradigm emerged and a new set of organizational structures with a potential to use for system building. Corporate organizations learned to vertically integrate downward to prevent competitors from interfering with the flow of inputs into their firms. Also, they learned to engage in collusion, price fixing, and other restraints to trade by forming cartels or trusts in the 1870s and 80s. Cartels were a group of firms with an agreement not to exceed certain prices and levels of production, and enter each other's territories. Trusts were a group of firms that allowed their stock to be held by a central trust that was charged with overseeing agreements between firms to collude and their general welfare. However, it was difficult for cartels and trusts to enforce agreements among their members. This was, in part, because these agreements were not enforceable under US law. If a cartel or a trust did manage to stabilize a market, this created a ripe opportunity for other non-cartel firms to enter that market, which set off another round of ruinous predatory change (Fligstein 1990).

With the enactment in 1890 of the Sherman Anti-Trust Act, cartels, trusts, and other agreements to restraint became illegal. There was considerable public support for the Act because the high prices of consumer products were attributed to collusion. However, the business community was extremely frustrated because collusion was one of the few ways that they had to stabilize price and supply and that was not mutually destructive. Despite federal enforcement of the Anti-Trust Act, many industries such as meat packing, steel, rail roads, whiskey, and gunpowder continued to collude with modest effectiveness into the 1900s (Fligstein 1990; Chandler 1980; 1962).

Because of the Sherman Anti-trust Act and the limited effectiveness of trusts and cartels, some manufacturers were seeking other ways to control price and supply. Many firms turned to *holding companies* as a solution. These were similar to trusts but existed as legally incorporated entities that held the stocks of each subsidiary company. Because they were a single legal entity, these organizations could not be guilty of collusion under the Sherman Anti-trust Act. The central offices did attempt with varying degrees of success to coordinate price and production among subsidiaries. However, even though the holding companies were comprised of subsidiaries that were legally integrated, there was no managerial integration. Central offices were without real authority, and original owners/managers of each subsidiary continued to operate rather autonomously (Fligstein 1990).

With the popularity of holding companies, the United States saw its first major merger movement from 1895 to 1905 (Fligstein 1990). Many of the firms that merged into single legal entities had been factory units that specialized in only one stage of production and often only one product. However, there was some managerial integration as well. Some of the companies had a significant amount of vertical integration by the time they merged into larger holding companies, and they continued to further integrate downward into raw material processing and manufacturing and upward into value-added manufacturing, distributing, marketing, and sometimes retailing (Chandler 1962).

Some of these holding companies became truly gigantic. The largest was the Northern Securities Corporation of New Jersey, which was a holding company with $22.2 billion in assets formed by J. P. Morgan and John D. Rockefeller in 1901. This would be a great deal of wealth in any day, but at the time it was massive. The holding company was equivalent to twice the assessed value of all property in thirteen states in the southern United States. "The heart of the American economy had been put under one roof, from banking and steel to railroads, urban transit, communications, the merchant marine, insurance, electric utilities, rubber, paper, sugar refining, copper, and assorted other mainstays of the industrial infrastructure" (Wasserman, 1983, 84). However, we must remember that although these holding companies were legally one consolidated entity, they were administratively dozens if not hundreds of largely autonomous organizations. By the end of the 1800s, most had yet to rationalize their internal structure into something that was manageable (Chandler 1962).

Second Crisis of Control: Lack of Efficiency among Functional Units

The economic effectiveness of these holding companies was mixed. The greatest benefits were yet to be achieved, which were large economies of scale from the increased efficiency of coordinating downstream production, upstream production, distribution and sales if throughputs could be better coordinated. However, this could not be realized until the parts of these behemoth holding companies were rationalized and integrated into a single management hierarchy for improved planning, information flow, control, and coordination. More *sophisticated and extensive management hierarchies* would become an important new organizational capacity for control.

Chandler (1977) argues that holding companies that formed just so they could avoid being prosecuted under the Sherman Anti-Trust Act did not survive. Although they were sometimes initially successful at restraining predatory trade, the resulting higher prices and stable markets attracted new competitors. Of the 317 holding companies that were formed from 1895 to 1905, only 46% survived until 1919, and most of the remaining went bankrupt or were swallowed up by even larger holding companies (Fligstein 1990).

Some of the holding companies began to recognize that they could increase profits if they improved the efficiency at which inputs flowed through each stage of production, into final products, and to the market place. Large-scale, mass production could lead to large economies of scale, but only if the flow and quality of inputs was well coordinated and if the expensive mass production facilities were kept in constant use (Womack et al. 1990). As the 19th century progressed, the speed at which inputs and outputs could flow increased with improvements in transportation and communication, and the benefits of coordination were more significant.

From the 1880s onward, some holding companies achieved more managerial coordination than others, and the paradigm of increasing profit through increased efficiency gained popularity. According to Yates' review of the historical research,

> Articles on managerial theory and technique appeared, first in engineering publications such as Transactions of the American Society for Mechanical Engineers and later in newly-created management publications such as System, Factory, and Industrial Management. This literature built up a new managerial philosophy—which . . . was later to designate "systematic management"—designed to achieve efficiency through system. One of the key underlying principles was the need for each level of management to evaluate and adjust the performance of lower levels in order to achieve greater efficiency. . . . This principle dictated the use of operating information as a basis for ongoing monitoring and comparison both over time and among operating units (Yates, 1989, 208).

One of the first to notice the benefits of coordination and managerial integration within a large company was the United States Rubber Company. When asked about the benefits, Mr. Flint replied

> The answer is only difficult because the list is so long. The following are the principal ones: raw material, bought in large quantities is secured at a lower price; the specialization of manufacture on a large scale, separate plants, permits the fullest utilization of special machinery and processes, thus decreasing costs; the standard of quality is raised and fixed the number of styles reduced, and the best standards are adopted; and the number of styles reduced, and the best standards are adopted; those plants which are best equipped and most advantageously situated are run continuously in preference to those less favored, in case of local strikes or fires, the work goes on elsewhere, thus preventing serious loss; there is multiplication of the means of distribution—a better force of salesmen takes the place of a larger number; the same is true of branch stores; terms a conditions of sales become more uniform, and credits through comparisons are more safely granted; the aggregate of stocks carried is greatly reduced, thus saving interest, insurance, storage and shop-wear; greater skill in management accrues to the benefit of the whole, instead of the part; and large advantages are realized from comparative accounting and comparative administration. . . . The grand result is, a much lower market price . . . (quoted in Chandler 1962, 33).

Other industry participants were also noticing the economies of scale that were made possible within holding companies if there was managerial integration and coordination (Fligstein 1990).

The National Biscuit Company had a similar experience at the turn of the century. In its first four years of existence, the company quickly went from thinking that success depended on looking outward at how to control the competition—either destroying or internalizing competition—to a radically different perspective of how to make profit. They began looking inward toward their own operations and focusing on how to better design the manufacturing process and coordinate operations for improved efficiency.

> We turned our attention and bent our energies to improving the internal management of our business, to getting full benefit from purchasing our raw materials in large quantities) to economizing the

> expenses of manufacture, to systematizing and rendering more effective our selling department, and above all things and before all things to improving the quality of our goods and the condition in which they should reach the customer. It became the settled policy of this Company to buy out no competition (see Chandler 1962, 32).

However, National Biscuit, the United States Rubber Company, and others reached the limit of how much coordination and integration could be achieved through holding companies. The original intention behind the design of this organizational form was avoiding anti-trust laws, not coordinating the stages of production. If they were to further improve efficiency, they needed to restructure their entire holding company. Specifically, they needed to better rationalize the relationship among all the parts of their organization and give the central office more control and coordination over those parts.

Probably the first high profile example of the functional form in the industrial world was the Ford Motor Company. Production at the Ford Motor Company was highly rationalized to quickly produce large numbers of affordable automobiles. He used a coordinated structure of a centralized plant (e.g. Highland Park, which went on line in 1910) that produced the major components such as engines and shipped them to decentralized branch plants that assembled them into automobiles along with additional parts supplied from local manufacturers. Branch plants also oversaw franchise dealers. All these activities were coordinated by middle and lower management whose actions were again coordinated by a complex set of policies from headquarters that reflected a coherent company strategy for low-cost, high-speed, high-volume mass production, distribution, sales, and service (O'Brien 1997).

Slowly, holding companies transitioned into centralized, multidepartmental firms with well-defined lines of communication and authority up and down a single management hierarchy, which would be the organizational form that would dominate the corporate world for decades. This new organizational form has been referred to as the functional form (f-form) because these firms organized their internal structure into sets of similar functional activities, such as purchasing, manufacturing, distribution, and selling. Each of these sets of functional activities comprised a department that was responsible to a central office.

This allowed for much greater central control and coordination of each stage of production.[22]

However, many business leaders, particularly original entrepreneurs/owner/managers, did not embrace the f-form. Their solution to their administrative problems was to find smarter, more energetic managers that could keep in even more personal contact with each part of the business. As noted by Chandler (1962), they were looking for administrators who could give

> careful attention to the administration of marketing, manufacturing, and procurement of raw materials and above all, form coordinating and integrating these different activities into a unified whole, [but realistically] only a man with enormous energy and highest intellect could keep in touch with all the activities of one of these vast new enterprises (p. 36-37).

This is understandable in the context of the way that many of these early captains of industry built their industrial empires. They did it through their bullish temperament, strength of personality, and creative ideas—not attention to organizational details.

> . . . the Rockefellers, Swifts, Dukes, Garys, and Westinghouses . . . had little time and often little interest in fashioning a rational and systematic design for administering effectively the vast resources they had united under their control (Chandler 1977, 36).

Most business leaders of the 1800s never gave much consideration to better ways to organize firms. Instead, they threw their companies together in an ad hoc fashion that was dictated by their perceived needs at the moment, their desires to amass and then admire their empire, fight predatory trade with their own predatory practices, and they took pride in their wrestling with the government over anti-trust laws. The men who assembled these industrial empires were not eager to break with the past. They had much pride and comfort tied up in the status quo (Chandler 1990; 1977; 1962).

The switch to the f-form involved a new wave of managers that were professionally trained, more intellectual, and liked administrative details—they were professionals. They seemed more apt to

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[22] A similar organizational structure had been used by railroad companies for decades, but had been organized around geographical areas of track and was referred to as the unitary form (u-form). Unitary

understand the root causes of their firm's organizational problems. They also seemed to have more skills to navigate through the subtleties of intra-organizational politics, which was important because the consolidation of power that was inherent to switching to the f-form never went without challenge. Most came from a manufacturing background and were educated in the new business programs at prestigious eastern colleges and universities (Chandler 1990; 1977; 1962).

To restructure their holding companies into an f-form of organization, these new professional managers consolidated some subsidiaries within their holding company, and liquidated the parts of those that did not fit into their organizational plans of a vertically integrated firm focused on a single end product or narrow product line. When the firm was missing a functional department from their planned organizational structure, they acquired another company to fill the need.

As functional departments were set up, central offices played a new role in the organization. While the departments were charged with carrying out the day-to-day functional activities of the firm, the central offices were charged with coordinating these activities. To do this, it was necessary to build a formal management structure with "carefully defined lines of authority and communication" running from a central office sufficiently staffed by professional managers to each functional department "with detailed, accurate, and voluminous" information flowing back to the central office (Chandler 1990, 37).

The activities and their corresponding routines and structures of these central offices fell into three categories. *First*, central offices were charged with coordinating and integrating the activities of the functional departments—purchasing, manufacturing, distributing, and selling—and the flow of inputs through these departments and goods into the market place. To achieve efficiency from vertical integration and to capture economies of scale, it was necessary to coordinate the kind, quality, and quantity of inputs that were bought by the purchasing department with the rate of production at each stage, and, ideally, with the level of demand in each market. *Second*, central offices evaluated the performance of each department and, also, their capital and labor needs, and then allocated resources based on those evaluations. *Third,* the central offices of large firms often built auxiliary or service

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comes from there being a single line of authority from all parts of the organization to the central office.

departments within the central office to handle specialized tasks for all the departments, such as purchasing and personal offices (Chandler 1962; 1977; 1990).

There is an important theoretical point that has yet to be made about the uses of organizational capacities. The benefits to system building from the increasingly complex management hierarchies—from the small business model, to middle management, to the f-form of organization, and to others yet to be discussed—lie not in an increase of capacity for control. Instead it is in their increased capacity for coordinating many different complex activities within a sociotechnical system. As Alfred Chandler noted, when corporations became massive, vertically and horizontally integrated firms, the increased demands upon management did not so much come from the increased size. Instead, it was from the increased complexity of business activity under one organizational roof (Chandler 1990; 1962; Fligstein 1990). Conversely, if this coordination did not occur among the random assortment of firms that comprised holding companies, there was the potential for diseconomies of scale (Yates 1989).

By the end of the 1920s, three-fourths of the largest 100 firms used the f-form (Fligstein 1990). However, many holding companies did not make the transition to the f-form. Of those holding companies that were not able to do so, most of them split into their constituent companies, went bankrupt, or were absorbed by others.

Conclusion and Additional Theory Building

This review of early corporate system building has illuminated a few ways that the concept of organizational capacities can be more specifically theorized. Also, this historical data suggests that the theory developed in Chapter 2 was too simplistic and in some ways misleading. The system building process was not always as straightforward and linear as was previously suggested.

These examples of early corporate system building pointed to specific organizational structures that can be used for organizational capacities and suggested that some of them are stronger sources of organizational capacities than others. Some of this is fairly obvious, and some of it is not. The existence of a head office is a precursor for the capacity to strategically plan, and for coordination, and it is a phenomenon that is distinct from management hierarchies. Holding companies were an example of an organizational form that had a head office, but little in the way of management hierarchies for gaining information about, and the control and coordination of the operating units of such organizations.

Management hierarchies obviously exist in different levels of complexity. These include the small business model that has a manager/owner directly overseeing most activities, the use of middle management, and also organizing functional activities into distinct functional units that each have their management that are supervised by the head office, such as in the f-form of organization. The utility of the f-form for organizations was to manage the complexity of various stages of production. This led me to theorize that the increased complexity of management hierarchies is usually not for greater control, but instead for the greater coordination of more complex system phenomena.

Also, it is theorized that management hierarchies provide better capacities for control, information, and coordination than do network relationships, although networks may often suffice. In most of the literature and examples reviewed, this was the case. The supply of inputs from down-stream manufacturers was often of undependable quantity and quality. Independent retailers usually refused or were unable to sell, service and repair new, complex, mechanical devices. Also, new inventions often needed new parts for an emerging system that did not yet exist, and it was necessary for the corporate system builders to create and internalize those parts into a management hierarchy. Although there were no examples of networks that provided better control, there were instances where networks appeared to suffice. The network relationship that McCormick eventually established with his independent dealers seems to be an example of this, and of course, to one degree or another all firms must rely on network relationships for some inputs and services. It is simply too expensive to internalize everything, and in many cases the benefits of doing so do not justify the costs. Chandler commented that early corporate system builders would usually not internalize a part if that part already existed in the system and if they could establish an adequate amount of control and coordination through network relations.

More importantly, the historical data suggested a problem with the conceptualization of organizational capacities as articulated in Chapter 3. All the capacities that were discussed as being held by corporate organizations from the 1800s through the very early 1900s in Chapter 4 were used to stabilize systems arrangements, such as to prevent predatory trade, and to efficiently conduct the core business activities of the corporate organizations. However, only to a limited degree were these capacities used for actually building new systems arrangements. The best example is perhaps the Ford Motor Company that went about creating new parts for emerging sociotechnical systems. Even though the company did use management hierarchies for system building it was not for ongoing, dynamic change. Ford used it to place many of these new parts of the system into its management hierarchy for superior control and coordination of these parts to more efficiently conduct business. Their management hierarchies stabilized the system arrangements. Using these management hierarchies to engage in their core, day-to-day, business activities functioned to *maintain existing system arrangements*. However, for Ford and other companies, once these new parts of the system were internalized into their management hierarchy, the head offices and their management hierarchies were not a major source of additional system building, and when it did occur it was nothing even remotely close to the more radical nature of their initial inventions, innovations, and system building. This will be more fully explored in the next chapter. The theoretical point will be that organizations often have organizational structures and routines to maintain existing system arrangements that are fairly distinct from structures and routines for building new system arrangements and controlling the pace and direction of sociotechnical change.

This theorizing helps us to better understand how organizational capacities manifest in actual organizational structures. However, the relationship between these organizational capacities and sociotechnical systems does not appear to be nearly as simple as theorized in Chapter 2. The development of complex, large-scale sociotechnical systems is typically a dynamic, emergent, and also interpretive process for organizations that are engaged in system building. Seldom is this process as simple as the cause-effect relationship that was suggested in the thesis of this study.

Organizational structures must be interpreted as capacities for system building if they are to be used as capacities to affect intentional consequences on sociotechnical systems. The structures that are viewed as capacities have changed with the period of history and, specifically, with the paradigms of the business community and the particular threats and opportunities that are experienced by that community reshape the system in intentional ways. This was the case with holding companies and their central offices during the period when predatory trade was the dominant paradigm in the business community. Holding companies were originally set up to allow firms to legally fix prices; negotiate output levels, and assign territories; the head offices of these holding companies were to oversee; and the meager managerial hierarchies of the era intended to help enforce these agreements.

However, under the paradigm of increasing efficiency, there was a change in the perspective on what an organizational capacity was and its uses. These holding companies and their meager managerial hierarchies were adapted to coordinate the flow of inputs through the stages of production and vastly improve efficiency. The next chapter will demonstrate the additional emergent characteristics of organizational structures. Specially, the adaptation of management hierarchies used as 19^{th} century organizational capacities to maintain existing system relationships were later adapted for use as 20^{th} century organizational capacities for system building—to control the direction and pace of technological change in a very dynamic, quickly changing sociotechnical system.

Much of these dynamics cannot be attributed to rational planning and decision making by system builders. Although some of the problems encountered by early corporate organizations were diagnosed and solved with clarity and vision, at other times these organizations were plodding forward with a very short planning horizon and trying to address problems as they arose on a week-to-week basis. No firm could have formulated and implemented a master plan that stretched across nearly four generations of corporate leadership that allowed them to develop from cottage industries of the 1850s to massive vertically integrated firms of the 1910s. As Alfred Chandler noted,

> "Just because the entrepreneurs make some of the most significant decisions in the American economy, they are not all necessarily imbued with a long-term strategic outlook. . . . Their decisions may be without forward planning or analysis but rather meeting in an ad hoc way every new situation, problem, or crisis as it arises" (1962, 12).

Charles Perrow adds the following.

> The process took place gradually over more than a century; the motivations for each small step were more prosaic than grand—controlling “ruinous” competition, keeping the work force in good condition, appropriating the profits of successful contractors by incorporating them . . . (1991, 743).

So then, what are the conditions that apparently led corporate organizations in the U.S. to develop superior organizational capacities for system building? This is an important question because it provides insight into the feasibility of alternative technology advocates acquiring more sophisticated and powerful capacities of their own. There appears to be a number of factors, and this chapter and Perrow’s comment hints at a few of these. *First*, severe external threats to an organization’s survival will sometimes prompt organizational restructuring. Predatory trade and anti-trust laws had this effect. Even when the intended use of new organizational capacities and structures was not implemented successfully, the new capacities provided a stepping stone for further system building and were adapted to other uses that were sometimes dramatically successful. An example was holding companies’ head offices and nascent management hierarchies being adapted for true vertical and horizontal integration. *Second*, it appears that developments in the larger meta-system suggest lucrative opportunities if corporate organizations restructure. For example, the development of an improved transportation and communication infrastructure made it possible to reach mass markets, but only if manufacturers restructured their management hierarchies to coordinate mass production with mass distribution and sales to mass markets.

Third, these dynamics appear to have a collective dimension that resembles the processes of institutional isomorphic change (Fligstein 1990) and also competitive isomorphic change (DiMaggio and Powell 1983) that leads to organizations in the same industry building the same organizational capacities and structures for the same purposes. Many early manufacturers were desperate for ways to deal with predatory trade, and with little evidence of actual effectiveness, they mimicked the solutions that were used by apparently successful corporate organizations such as Standard Oil and railroad companies who used trusts and holding companies. The same dynamics appear to have occurred with the adoption of the f-form (Chandler 1962; Fligstein 1990). However, the high survival success of holding companies that transitioned to the f-form and reports of observed benefits and intentional decision making suggests competitive isomorphic change (Chandler 1962; Fligstein 1990; Yates 1989; Ford 1922; 1926) played a role in firms converging on the f-form.

These findings are frustrating to one of the efforts in this study to develop a practical, hands-on theory of system building. If capacities for system building are significantly due to factors beyond the control and intention of management, then it might be difficult to construct an empirically valid theory and a set of recommendations that can be used by management to better control sociotechnical change.

If it had not of been for the sudden expansion of national markets and the Federal Government's anti-trust laws, it is hard to imagine how the cottage industries of small scale local manufacturers of the 1850s would have so rapidly assembled themselves into much larger, centralized, vertically integrated, multidepartmental organizations that controlled most of the important supply-side parts of their sociotechnical systems by the beginning of the 1900s. Eventually some probably would have, but perhaps it would have taken a half century or more. The importance of these external threats and opportunities to the system building process is underscored by the fact that U.S. corporations entered the industrial revolution about 50 years behind Europe, but in the years between WWI and II, many U.S. corporations had gained dominance over their European counterparts. Fligstein (1990) and Chandler (1980) point out that in most of Europe there was no anti-trust legislation, less of a problem with predatory trade, and few mass markets to encourage the adaptation of large-scale, centralized, multidepartmental, vertically integrated, corporate organizations.

Chapter 5: Systemizing the Process of Technological Change

There were significant differences between system building in the 1800s and early 1900s compared to system building in the rest of the 1900s. In the earlier period, capacities were primarily used to defend against predatory trade and anti-trust laws and to efficiently coordinate the flow of inputs through firms. These were organizational capacities that were mainly used for stabilizing and maintaining the existing system. Then during the rest of the 1900s, corporate organizations developed capacities that were specifically for system building, and that let them to dynamically control the pace and direction of technological change. These capacities for system building were manifested as strategically focused central offices, the multidivisional form of organization, R&D units, and marketing departments.

The capacities to maintain existing system relationships were crucial stepping-stones for the capacities for system building. As will be discussed, in the 1910s a number of firms developed specific routines for R&D and integrated them into the management hierarchies of the f-form. These management hierarchies were essential to coordinate R&D with the rest of a firm. Furthermore, firms developed organizational routines for strategic evaluation, planning, and oversight, located these routines in the head offices that had already been established, and again the existing management hierarchies were essentially gathering information on parts of the system that were needed for these strategic activities. Also, for many corporations, the f-form of organization was an effective set of capacities to generate profit that could be used to fund R&D and other system building. Actually, in those firms with both extensive capacities for maintaining and for building, the parts that are for maintaining existing system arrangements can be viewed as the capacity for generating financial resources for the system building that was conducted by the other half.

This chapter will explore these system-building activities. Some additional theorizing will then focus on which specific organizational structures make the most effective organizational capacities used specifically for system building, how they are used, and to what effect.

Routines for Invention and Innovation

It may seem strange that anyone would want to make the process of inventing into a routine. Invention implies making something new—a break with the past—and making it into a routine would seem to make that goal more difficult to achieve. However, during the 1900s, corporate organizations intentionally structured the processes of inventing and innovating into a set of laboratory and administrative routines that they could control (Teece 1988; Nelson and Winter 1982; van den Belt and Rip 1987; Hughes 1989). Joseph Schumpeter wrote in 1942 that

> [Creativity and entrepreneurship by individuals] is already losing importance and is bound to loose . . . at an accelerating rate in the future . . . innovation itself is being reduce to routine. Technological progress is increasingly becoming the business of teams of trained specialists who turn out what is required and make it work in predictable ways (p 132).

When I refer to routines for inventing and innovating, I am not implying that there are routine answers to technological problems. Instead, I am stating that invention and innovation have increasingly become a set of structured set of behaviors for scientists, engineers, and other professionals to go about answering technological and scientific questions in an organizational setting, such as corporate R&D labs.

Has reducing invention and innovation to a set of routines stifled creativity? Perhaps. Actually, doing so appears to have been the intention of corporate organizations. However, rather than completely stifling creativity, it is probably more accurate to say that they have wanted to control creativity to steer the inventive and innovative process away from technical problems and solutions that would add little to, or even threaten, the existing sociotechnical system and toward those that fit with their strategic plans to expand and elaborate their control of that system. Radical new technical inventions can obviously pose enormous risks to established organizations with a vested interest in the existing sociotechnical system. However, more modest and carefully chosen technical inventions can help an established corporate organization elaborate and expand its organization and sociotechnical system and also its control over that existing sociotechnical system.

Thus, there is something much more important to corporations that creativity. It is their ability to control creativity to find new technologies that allows it to expand, elaborate, and gain more control over its relevant sociotechnical system. When an activity within an organization is converted into a routine, it becomes controllable by the management in a number of ways. As they deem necessary, management can tell staff to engage in a particularly routine. When staff gains experience with a routine, they typically become very proficient at it and generate predictable results when they engage in that routine behavior or decision-making. Also, when most behavior in an organization is converted into a set of routines, everyone in that organization generally knows approximately what to expect from individuals and what kind of outcomes to expect from their collective actions. Thus, by integrating individual routines together, organizations can engage in complex tasks that can be coordinated by a central office often without much direct oversight of day-to-day details. One of the early leaders in product development held the belief that

> specialized routine results in the formation of correct working habits, reduces errors to a minimum, establishes a standard method of work that is common to everyone in the office, lessens the strain on individuals, is more expeditious than optional individual methods, and frees higher-salaried employees from details that can be done by lower-salaried employees (Geddes cited in Meikle 1979).

By developing routines for research, development, and marketing, management has gained a much greater ability to control technological change and also to predict and control how technical innovations will affect the rest of the organization and sociotechnical system. If creativity has been stifled in the process, it was a very small price to pay. By citing Thorstein Veblen, the philosopher Herbert Marcuse aptly summed this up.

> The necessity that is the mother of invention is to a great extent the necessity of maintaining and expanding the apparatus. Inventions have "their chief use . . . in the service of business, not of industry" [nor really society] . . . They are mostly of a competitive nature, and “any technological

advantage gained by one competitor forthwith becomes a necessity to all the rest, on pan of defeat" (1941, p. 419-420).

The phrase "research and development" or "R&D" is an overlapping term that refers to many similar activities—basic research, invention, innovation, development, and product development—all of which need to be defined. Although these are not always distinct processes in actual practice, *basic research* refers to the investigation of the underlying physical, chemical, or energetic properties of a particular technology or phenomenon. *Invention* refers to the creation of a new technology that will allow humans to accomplish a particular technical goal, which is conducted by scientists or engineers. Corporate sponsors expect that both basic research and the inventive process will lead to a steady stream of new inventions. However, from their conception, most inventions are quite crude and often are 5 to 15 years away from being marketable. *Innovation* and *development* are essentially the same concept that refers to the processes of "working the bugs out" of an invention—whether it is a new process, piece of manufacturing equipment, or a new product—and integrating that invention into the larger system. When this invention is a new product, this process is usually referred to as *product development*, and integrating it into the system involves developing a production process and successfully introducing it into the market. This is both a technical and social endeavor that requires a close collaboration between engineers and marketing professionals (Callon 1987).

In other words, innovation is the general process of integrating an invention into the larger sociotechnical system, which involves obtaining information on the invention and the larger sociotechnical system, evaluating the fit between the invention and the larger system, and then deciding how to redesign the invention and/or reshape the larger sociotechnical system to improve the fit. New inventions such as these can be either new productions or new production technologies. In the 1900s, product development became one the central system-building activity in which industrial corporate organizations engaged. In theory, invention can include both technical and social inventions, but for the purpose of this chapter I will restrict my discussion to only the technical.

Between that of research and that of development, corporate organizations devote considerably more time and money to development. This is because it has always been much more difficult, time consuming, and expensive to integrate a basic invention into a system and successfully bring it to the market than it has been to invent. In addition, corporate organizations have tended to rely heavily on university labs for a large majority of their new scientific knowledge and basic inventions, which along with government, bear much of the expense for basic research and invention. For corporate organizations, new inventions have usually been “a dime a dozen” relative to marketable products. Successful innovation has always been the most expensive and difficult to obtain, but it has also been what ultimately brings a profit (Hughes 1989, Reich 1985, Hounshell and Smith 1988).

Marketing became probably almost as important to controlling technological change as R&D labs. This is because marketing became invaluable to firms for integrating the characteristics of an invention and the production process with the perceived needs and desires of buyers and the volume of demand in the market place. Marketing departments/offices started to gain prominence among corporate manufacturers in the 30s and 40s, slightly before R&D labs, suggests Fligstein (1990).

However, it has not always been this way. During the 1800s, marketing was rarely conducted and the inventive process was the domain of the independent inventors.

The Independent Inventors

The independents inventors that dominated the process of invention in the 19th century included both professionals and amateurs. The difference was that professional inventors spent their lives on many different inventions and drew their livelihood from the income of their market successes. These included Thomas Edison, Elmer Sperry, and Nikola Tesla who tended to have their own well-staffed and equipped laboratories with many different inventions underway at any given time (Hughes 1989). Conversely, amateur inventors tended to focus on a single invention and relied on a second source of income during the inventive process. However, their status as “amateurs” does not appear to have decreased the sophistication of their approach to invention or their ingenuity. The famous amateurs of the 1800s included Cyrus McCormick, Isaac Singer, Orville and Wilbur Wright, and Alexander Graham Bell (Hughes 1989). There were no doubt a large number of amateurs that tinkered in a shop behind their homes and made smaller contributions to history that have since faded into obscurity.

The most common characteristic of these independent inventors is that they avoided salaried positions and long-term commitment with large-scale industrial enterprises and, thus, they were able to choose their own inventions to pursue. However, they relied on other organizations to manufacture and market their inventions. By leaving manufacturing and marketing to others, they could return to inventing and retained their independence (Hughes 1989). Subsequently, independents have invented much more than their share of the radical inventions of history (Jewkes et al. 1969). By radical, it is meant that these independent inventors were responsible for the technologies that provided the nuclei for new sociotechnological systems. Conversely, the inventors who have worked for established industrial organizations have had the more conservative charge of improving existing systems (Hughes 1989).

> [Most established] "organizations did not support the radical inventions of the detached inventors because, like radical ideas in general, theirs upset the old, or introduced a new nurturing institutions. Such inventions often de-skilled workers, engineers, and managers, wiped out financial investments, and generally stimulated anxiety in large organizations . . . In the late nineteenth century, gas lighting, railroad, and the telegraph companies did not preside over the invention and development of electric lighting, the automobile, or the radio. Independent inventors brought them into being, along with the new companies and utilities needed to nurture them (Hughes 1989 p. 54).

Because they were independents, they had to find their own funding, and since their inventions were often a threat to established sociotechnical systems, existing manufacturers were rarely interested in funding the inventive activities of these independents.[23] Financing usually had to come from investment bankers, lawyers, and individuals who made their money from unrelated industries (Hughes 1989).

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[23] At the beginning of the 20th century, the military began a concerted effort to increase their technological sophistication and they became another market for inventions (Hughes 1989).

Most would probably say that many inventors in the 1800s were a bit quirky. This was a signature of their independence from the routines of large-scale corporate organizations, and reminds us just how different the process of invention was from that of today now that it has been rationalized, routinized, and systematized. Many independents invented as much for the personal thrill of it as for profit. More than any other independent inventor of the era, Nikola Tesla seemed to care little about the marketability of his inventions except that he needed profits to pay for more inventing. Perhaps best described as a Mr. Science/David Copperfield of his time, Tesla led a flamboyant lifestyle and cherished “his dramatic experimental demonstrations of his discoveries and inventions in the field of high voltage electricity . . . For those who were in awe of him, he exuded an air of mystery arising, it seemed, from his communion with cosmic creative forces” (Hughes 1989 64-65).

Inventors could not just rely on their creativity and technical prowess to succeed. They also need skills in public relations and raising funds for pursuing new inventions, and it seemed to help when they encouraged a bit of mystique about their work and mingled it with curiosity and awe. A substantial portion of investors had little understanding of the technical details of the inventions in which they were asked to invest. At a time when there were not yet procedures for market analysis and profit forecasting, showmanship was at a premium (Hughes 1989).

Internalizing the Capacity to Control Technological Change

Starting in the 1890s and culminating in the 1920s, independent inventors play a decreasing role in the origination of new inventions and were gradually replaced as firms established their own R&D labs. At first, firms did so to improve products and processes and then later to invent new ones (Teece 1993). A few corporate leaders in particular—Standard Oil, AT&T, General Electric, DuPont, and Eastman-Kodak—were the first to set up their own R&D laboratories. These corporate organizations used their laboratories to address technical problems of their own choice and to produce solutions that would increase their control over the existing sociotechnical system, which was in direct contrast to the goals of most independent inventors (Dennis 1987; Hughes 1989; Chandler 1990; Hounshell 1992; Reich 1977).

By the 1930s, a growing number of companies had established a core set of R&D capabilities and were able to generate a relatively dependable and predictable stream of new products while constantly making improvements in existing products (Lazonick and West 1998, 261).

However, before R&D labs became mainstream, the corporate world had to undergo a paradigmatic change about how they viewed the relationship between society and technology. As previously discussed, a dominant business paradigm during the latter half of the 1800s was to increase profit by controlling the market through predatory trade and collusion to stabilize price and output. That version of system building and control was later supplanted by the manufacturing version at the turn of the century that encouraged the rationalization of the production process to increase its efficiency and lower price. Controlling technical change was not part of these two paradigms. This is consistent with the pre-enlightenment era and its associated fatalistic, rather static view of the world that was predominant in the 1800s and still held a foothold in the early 1900s. The state of the world and the larger processes in society and nature were controlled by God and fate, and there was little humans could do to change that. Until the turn of the century, science was seldom considered by businesses, government, or the public as a way to predict and control nature or society for human benefit (Worster 1994; Hayes 1959).

Since at least the civil war, scientists and laboratories were used by corporate organizations, but they were not research scientists and the laboratories were not research laboratories. Instead, industry made use of production laboratories that were staffed by scientifically trained technicians as part of the manufacturing process to test the quality of inputs, monitor the efficiency of the manufacturing process, and test the quality of outputs. In other words, they were charged with maintaining the production process, not producing new knowledge and inventions (Dennis 1987; Hughes 1989). Outside these activities, corporations had very little capacity to solve technical problems that arose, and had to rely almost entirely on buying new inventions from independent inventors. When they had a specific technical problem, occasionally they would temporally hire an independent inventor to solve it. Manufacturers thought that the process of invention was largely uncontrollable, and those who did invent were slightly peculiar and had an “inventive temperament” (Reich 1985, 146) that had contact with “cosmic creative forces” (Hughes 1989, 64-65) and a personality unsuitable for working in a factory environment (Dennis 1987; Chandler 1990). Also, there is evidence that in some firms the details of the manufacturing process were held by a trusted foreman as trade secrets, and kept away from laboratory scientists. This, of course, made it very difficult for laboratory scientists to make original contributions to improving the production process. The division of labor was such that independent inventors made new inventions, academic laboratories produced basic scientific knowledge, and industrial corporate organizations took advantage of these inventions and scientific knowledge to process raw material and manufacture products (Dennis 1987; Hughes 1989).

However, around the end of the 19th century, a contradiction emerged between the existing corporate view of technology and that of observation and experience, and it appears that beliefs about technology started to change. Corporate organizations were experiencing a new crisis of control. Independent inventors had generated a wave of inventions that threatened existing sociotechnical systems and the ability of established firms to control their markets. This time the crisis was a lack of control over technological change. They had been relying almost entirely on independent inventors for patents to new inventions, and had no guarantee that these independents would generate the inventions they needed or that they would sell patent rights to them instead of their competitors. Especially as the pace of technological change quickened, it became too risky to rely on independent inventors (Hughes 1989; Dennis 1987).

Likewise, established corporate organizations wanted conservative, incremental inventions to refine, elaborate, and expand their established sociotechnical systems, such as the telephone system, electric lighting and the electrical system, and photographic technologies. Although independent inventors had originally been the driving force behind the emergence of these systems with their radical inventions only a few decades prior, independents usually did not want to spend much time on the further development of them. Often they wanted to pursue something entirely new—another radical technology that would be another nucleus for the next revolutionary sociotechnical system. Thus, independent inventors often did not produce the kind of inventions that the new industrialists needed to elaborate and expand their relevant system and enhance their control over that system (Hughes 1989).

Also, to produce the incremental improvements that were needed by established firms, it became increasingly important to have advanced education training in chemistry and physics to explore basic scientific properties behind the technologies that were the nucleus of these systems. Many independent inventors did not have this education. Instead, corporate laboratories recruited from a growing number of trained scientists and engineers that came out of the new science programs at US universities (Reich 1985; Hughes 1989).

The fear that other firms may gain access to an invention before they did was also a motivation for corporate leaders to establish in-house research laboratories. As a defensive move to keep control of the market that they already had, a few corporate leaders set up in-house research labs. Edison Electric set up their research lab because they were worried about another firm inventing and patenting a better incandescent light. Eastman-Kodak was concerned that someone would invent color film, which prompted the company to set up a research facility. DuPont, which was primarily a company that manufactured dynamite and black powder, foresaw a serious problem with unused capital between wars. In an effort to find other ways to use their manufacturing facilities and larger organization, DuPont 's "Experiment Station" made important advancements in "smokeless gunpowder" among other things. American Bell Telephone established their research lab because Bell's original patents expired and it became more difficult to win infringement suits against competitors (Chandler 1990; Dennis 1987; Reich 1985; Hughes 1989).

Although corporate organizations undertook R&D efforts to defend against threats, their use of research was extremely conservative. Most of their efforts were devoted to modifying the inventions of outside inventors so as to better integrate these into its relevant sociotechnical system. In the process, firms often produced conservative, incremental inventions of their own that were patentable, but rarely anything truly original.

Nevertheless, the early successes of these R&D labs gave their firms good reasons to take invention and innovation more seriously and think about other uses for R&D. With the inventions of the electronic repeater, tungsten light bulb, smokeless gunpowder, and artificial leather, the R&D laboratories in each of these corporations clearly demonstrated their ability to control technical change to defend existing market share. These early R&D labs soon had the support of their larger corporate organizations to tackle a wider range of technical problems and pursue lucrative inventions. They were not disappointed. R&D capabilities allowed companies to take the offense by expanding their control of existing markets and enter new ones. Eventually, entire laboratories were set up to conduct R&D on most of the major technical components of these organizations' production technology and many of components of its larger sociotechnical system that they hoped to better control (Reich 1985; Fligstein 1990).

Integrating the Capability to Invent within the Firm

"Isolated laboratories" within a corporation's organizational structure did it "little good." For Bell, GE, DuPont, GM and others to use R&D labs to their full inventive and system building potential, "industrial research had to be thoroughly integrated" and rationalized with the rest of the organization including product development laboratories, the engineering department, production, marketing, and the strategic plans of top management (Reich 1985, 243). Invention and particularly innovation is an organization-wide activity.

Two factors were of importance regarding how to rationalize and integrate R&D laboratories into the existing firm. First there was the issue of where to locate R&D within the existing organization, and, second, the type of relationship it should have with the rest of the firm. The corporate R&D laboratories that emerged were much more than the independent invention factories set up by Thomas Edison. The corporate labs were managerially separate from manufacturing but were also well integrated through lines of communication with the rest of the organization.

R&D laboratories had originally been part of manufacturing operations, which meant that they were supervised and directed by the same middle managers who oversaw manufacturing. Although this allowed R&D labs to keep in touch with the technical problems associated with production, it also made it unlikely that R&D would be encouraged or even allowed to pursue research problems and solutions that could threaten existing manufacturing technology. If R&D was to pursue novel new inventions, they needed autonomy from the parochial interests of manufacturing and other parts of the firm. Thus, corporate frontrunners in industrial research broke with tradition and created labs that were organizationally separate from manufacturing so that R&D and manufacturing were run by different middle managers. These new labs were located within newly created R&D, new products, or marketing departments/offices. Other times top management located the administration of R&D labs in their central office so they could control these labs outside the department structure. Maintaining this calculated distance from existing manufacturing allowed labs to pursue inventions that were somewhat more radical—that were for the long-term benefit of a firm even if such inventions undermined the short-term, parochial interests that were aligned with existing manufacturing facilities. However, because manufacturing departments still had to find technical solutions to minor problems that arose in the production process, they were often allowed to keep or establish their own limited engineering/R&D laboratories (Reich 1985; Hughes 1989; Hounshell and Smith 1988; Dennis 1987).

Second, steps were taken to make sure that these autonomous R&D labs were still well integrated with manufacturing and additional measures were taken to integrate it with the rest of the firm. This integration was accomplished by sets of routines that were primarily lines of communication with other parts of the organization including manufacturing to insure that R&D pursued inventions and research questions that were consistent with the firm’s overall strategy and that could be reasonably integrated into the larger organization and system.

More specifically, formal and informal routines were developed to gather performance and market information about new inventions, evaluate the fit between the invention and the rest of the organization, and decide whether to redesign the invention or reshape the system to improve that fit or to abandon the particular R&D project. Very simply, these routines were for control, and made the process of invention orderly and efficient. Most of all they ensured that top management controlled the overall direction of

R&D so that any new inventions could be fitted into the systems according to their plans. Some routines were laboratory routines structured by scientific method and theory. Others were managerial routines, which were rationalized by management strictly for the purpose of control.

German chemical dye companies as early as 1880 had developed laboratory and modern research routines based on science. Just as with their early 20th century US counterparts, these laboratories were separate from, but still integrated with, manufacturing. They also used the scientific method to routinize and thus control the process of invention and then used additional routines to fit the invention to the rest of the system.

> The number of routine experiments that had to be conducted to find a single promising color [for a new dye] was large. When such a color was discovered, it was sent to the dye-testing division, where it was subjected to a battery of tests to indicate whether and under what conditions it would tint any one of the common fibers, or such other items as wood, paper, leather, fur, or straw. Then each item successfully tinted was subjected to several agents of destruction to determine fastness. 0f the 2,378% colors produced and tested [by Bayer] in the year 1896, only 37 reached the market. This tedious, meticulous experimentation, in which a thousand little facts were wrenched from nature through coordinated massed assault, admirably illustrates the method and spirit introduced into scientific inquiry by the rising industrial laboratory of the late nineteenth century (Beer 1958, 130).

Research in a modern laboratory involves a great deal of routine via the structuring influence of scientific theory and methodological procedures. This gave control to organizational system builders. In contrast to the heavy empiricism of “hunt and seek” approaches to research (Reich 1985, 15), the state of scientific theory in many fields of the late 1800s and early 1900s allowed research scientists to construct laboratory routines with outcomes that they could reasonably predict. As was noted by one observer, “the trained man has shown the possibility of predicting results theoretically which previously had to be determined experimentally, at great expense . . .” (Lang cited in Reich 1985). The ability to construct research agendas with relatively predictable outcomes allowed top corporate management to align the

R&D process with the strategic goals and tactical needs of the firm. Corporate R&D has advanced to the point that management can reasonably expect that R&D labs will generate a stream of inventions to help expand and elaborate their sociotechnical system with much greater control than was previously possible (also See Thomas Kuhn 1962) than when they had relied on more primitive invention factories of Edison and others. Also, see the below discussion on DuPont's invention and development of nylon for additional evidence.

Of course, we should be careful about attributing too much rationality to the R&D process. Not all research can be reduced to protocols, and of course is it not possible to always predict the outcome and its impact on the rest of an organization. R&D still often results in dead ends and, also, leads to new discoveries that push R&D in entirely new directions. However, to the extent that scientific and technical advances can be predicted and controlled, R&D labs have become powerful tools for corporate organizations.

Other routines were managerial in nature. They linked the processes of invention with that of development, and, most importantly, linked the processes of product development with the rest of the organization and sociotechnical system. When, for example, product development was occurring, the associated routines included the transfer of information, equipment, and sometimes personnel from R&D labs to that of manufacturing for the building of a pilot plant and testing of the manufacturing processes for the new product. Other routines include checking with purchasing to see what inputs are available in-house, what needed to be outsourced, or what new abilities to manufacture inputs needed to be developed, assessing the capabilities of the existing manufacturing processes of the corporate organization, gathering qualitative information from the sales department on the needs of customers, obtaining quantitative market research data, also, increasingly in the 20th century, coordination is needed with the legal department on regulations pertaining to the product or process and the chance of effective enforcement of such regulations. Some of these routines have been sets of routines, some have been formal policies, and others have informal interactions that people learn from experience and new employees pick up by imitation. Regardless, all were very common practices during the course of an R&D project (Reich 1985, Hounshell and Smith 1988; Chandler 1990; Dougherty and Corse 1997).

In many cases, corporate R&D routines are broad and allow a great deal of individual discretion. Likewise, many routines can be flexibly used, and have contingency criteria that can trigger other routines depending on the situation (see March and Simon 1958 for a similar treatment of routines). For example, at each stage in the R&D process, decision makers assess the fit between an invention and the rest of the system, and decide where to make adjustments. Also, criteria are used to predict if an invention might be profitable. Based on still other financial criteria, management then has the flexibility to decide to continue the R&D project and at what level of funding, redesign the product or process, and/or make changes in other parts of the organization or the broader system, or terminate the R&D project.

The Emergence of Modern Marketing

That "the customer is always right" now hardly seems novel. However, at the beginning of the 20th century it was a fairly new concept that the tastes and needs of customers should be systematically considered when designing a product, and that a full range styles, colors, and models can capture a larger market share than a single product design. It was even more radical that frequent product improvements, style changes, new models, and the well-planned and aggressive advertising of these changes could manipulate market demand, and expand market share and take market share away from competitors (Fligstein 1990; Clarke 1996).

In the 1920s, corporations began to widely realize that their ultimate organizational goal was selling. It was not *per se* manufacturing, controlling prices, or trying to ruin the competition as had been emphasized in earlier eras (Fligstein 1990). They also realized that their success at selling was heavily dependent on two things that previously had not been emphasized: the technical/physical attributes and style of a product and what potential buyers thought of these product attributes. As Fligstein (1990) describes, their attention to these issues leads to new techniques to control the market that included finding new products, finding new markets for existing products, establishing brand loyalty, differentiating a product from a competitor's product so as to avoid direct competition with the products of other firms, expanding market share through advertising, and continuous efforts to improve every product in a product line. The success of these methods made it even more obvious that technology and consumer demand was not static. Both were quickly changing, and for firms to be competitive they had to be able to understand these changes and be able to exert at least some control over them (Reich 1985; Benniger 1986).

According to Church (1999, 425), before the 1920s, the salesman was the only real source of information about and control over consumers. As "the bridge between producer and consumer," the salesman would provide feedback about who their customers were, what customers wanted, and the quantity of products that were demanded. However, it was the engineer (who was also often the original entrepreneur/owner) who kept tight control over product characteristics and who often designed his own advertisements in the form of posters and newspaper advertisements. With little integration between the sales staff and manufacturing, the technical attributes and efficiency of production tended to weigh very heavily on product designs and advertising. For individuals that were engaged in advertising, sales, and product design, their contribution to market success was largely dependent on their own skills of perception and persuasion, not routines to scientifically gather to information about market demand and systematically shape consumer preferences (Fligstein 1990; Chandler 1962; 1990; Walker 1996).

From these humble beginnings, elaborate marketing departments started to evolve and came to be staffed by advertising, market research, R&D professionals, and marketing professionals that executed complicated routines to shape both product characteristics and market demand for those products. In the 1920s, advertising, marketing, and product development became recognized as professions that had a formal role in corporate organizations, and soon the marketer had as much if not more to say about product design as did the engineer. The marketing professions came to use a sophisticated set of specialized capabilities and skills that make heavy use of the social and psychological sciences. In addition to the traditional activities of sales and advertising, modern marketing includes special skills and organizational routines for market research, product design, product testing, and a full array of customer support to help ensure repeat customers—all of which grew, or developed substantially, during the emergence of modern marketing in the 1920s (Chandler 1990; Fligstein 1990).

Nationwide there was an increase in advertising from $500 million in 1921 to $1.5 billion in 1927. Then in 1946 it grew to $3.2 billion and close to $10 billion in 1950. Market research and forecasting grew as well. By 1947 the money spent on market research had increased to $50 million from less than $10 million before the war. Over 44% of the firms that did over $5 million in business had market research departments, and over 72% of firms of any substantial size were already engaged in market research of some kind (Fligstein 1990).

All firms did not develop an internal capacity for each aspect of modern marketing. Some outsourced. Particularly, the smaller firms contracted out for capabilities such as market research and the formulation of advertising campaigns. However, to successfully exert control over demand in the increasingly competitive markets of the 1920s, 30s, and 40s, it became accepted for industrial corporate organizations to have a marketing staff of some sort that either conducted these activities in-house or provided coordination between a manufacturing firm and external marketing firms (Fligstein 1990; Reich 1985; Chandler 1962; 1990; Meikle 1979).

Both marketing and R&D became essential parts of corporate strategy. Continual invention, product development, and control of market demand became the central pillars of corporate strategy for a larger percentage of firms. The influence of the marketing department was elevated in the corporate organization and given more direct lines of communication to the central office than other departments, and product development and marketing was placed at center stage in all discussions of strategy, further rationalization, and restructuring of the firm. Top CEOs tended to be from a marketing or sales background compared to manufacturing (Fligstein 1990).

Using R&D and Marketing for Systems Building

Depending on their different needs for system building, corporate organizations adopted different approaches to R&D and marketing. For example, producers of high-volume consumer items for a mass market—such as processed foods, consumer non-durables, kitchen appliances, and automobiles—spent large sums of money on sophisticated marketing. For those who sold highly specialized products to supply-side customers in limited quantity, mass advertising was not cost effective. Instead, less expensive, highly targeted advertising and promotions were used to exert control over demand. Also, corporate organizations that sold technically complex products (e.g. office and industrial equipment and chemical feedstocks) often needed to make substantial investments in customer support capabilities such as warrantee offices, repair and maintenance staff, and technical staff to provide user information and trouble-shooting advice (Chandler 1980; Chandler 1990; Fligstein 1990).

Similar can be said about the use of R&D. Corporate organizations developed different ways to manage the R&D process as a means to control technical change. This depended on whether research was heavily guided by scientific theory, whether the technological points of resistance in the system could be specifically defined, and whether consumer tastes were stable or changed quickly. A few examples are beneficial to understanding how different firms used R&D and marketing for system-building activities. Ford, GM, DuPont, and AT&T were chosen because they were early leaders in R&D and/or marketing. Also the existing research on these companies is quite good and allows me to illustrate a range of concepts.

Automobile Industry: The Ford Motor Company and the Model-T

The auto industry has focused its R&D and marketing on the technical nucleus of its relevant sociotechnical system, which of course has been the automobile. As mentioned in Chapter 3, most of the infrastructure for the auto-centered surface transportation system was being developed through very decentralized efforts that did not need the money and coordination of the auto manufacturers. This allowed automakers to focus on improving the auto. From the start, autos were expensive, complex machines, and early models were not user friendly and prone to mechanical failure. These problems needed to be rectified if the early auto industry was to create larger markets for the automobile.

Ford Motor Company is not usually known for doing so, however, it was the first automaker to make a serious contributions to the modern marketing of autos. Although his approach had serious weaknesses, he was the first to create a mass market for autos, and the company did this by accurately assessing characteristics of market demand and then integrating production with that demand. However, it had a static view of the world, and he did not build into his organization the ability to dynamically adapt to changes in technology and the market. When these things did change, the company did not, and it floundered.

Ford was like all other automobile manufacturers in the first two decades of the 20th century. It made a very limited number of models in a handful of styles with only haphazard product improvements and style changes from year to year if any were even made. Product design was primarily influenced by what was the easiest to manufacture and what engineers thought to be technically elegant, and not systematically considering what customers wanted (Fligstein 1990; Walker 1996). As a case in point, the Ford Motor Company manufactured a single model, the model T, relatively unchanged for almost two decades. Henry Ford describes his reason for doing so.

> Ask a hundred people how they want a particular article made. About eighty will not know; they will leave it to you. Fifteen will think they must say something, while five will have preferences and reasons. The ninety-five, made up of those who do not know and admit it and the fifteen who do not know but do not admit it, constitute the real market for any product. The five who want something special may or may not be able to pay the price for special work. The majority will consider quality and buy the biggest dollar's amount of quality. If, therefore, you discover what will give this 95 percent of the people the best all-around service and then arrange to manufacture at the very highest quality and sell at the very lowest price, you will be meeting a demand which is so large that it may be called universal (pp. 47-48).

It was from this perspective that Henry Ford boasted that a “customer can have a car painted any color that he wants so long as it is black" (Ford 1922, 68).

For almost two decades, this strategy worked well for Ford. The company's large-scale mass production facilities produced quality autos at a lower price than competitors. Specializing in one model did offer economy of scale advantages that other manufacturers had not yet been able obtain. In 1921, Ford rose to his all time dominance with control of 55% of auto market amidst hundreds of competitors, such as GM and Chrysler and small companies such as Cord, Studebaker, and Kaiser.

However, by the mid 1920s the Ford Motor Company was facing serious competition from General Motors (GM) and other competitors that had adopted and then improved upon Ford's techniques (Dalton 1926 cited in Chandler 1962). The most successful of these innovators was GM, which produced a full line of automobiles with yearly model changes that kept up with changes in technology and consumer preferences. In 1927, even Henry Ford realized that the model T needed to be fundamentally redesigned, and the Ford Motor Company switched to another single model, the model A, to reflect new technology and driving habits. However, by then his control of the market had dropped to a dismal 9%. Within a few years, sales increased but the company never fully covered (Fligstein 1990, Nevins and Hill 1957, Bardou 1982; Federal Trade Commission 1939). Henry Ford has often been referred to as a manufacturing genius, and GM has been heralded as the marketer genius, but that is too simplistic.

Despite these shortfalls, under Henry Ford's leadership, the Ford Motor Company made significant contributions to modern marketing. Ford was one of the first major manufacturers to recognize that market demand could be increased by carefully designing a product with mass-market appeal. When other car makers were producing luxury cars that few could afford, Ford asked the question: What does this multitude of potential new car buyers want in an automobile? (Fligstein 1990). In Henry Ford's own words . . .

> A motor car was still regarded as a luxury. The manufacturers did a good deal to spread this idea. Some clever persons invented the name "pleasure car" and the advertising emphasized the pleasure features. The sales people had ground for their objections and particularly when I made the following announcement: I will build a motor car for the great multitude. It will be large enough for the family

> but small enough for the individual to run and care for. It will be constructed of the best materials, by the best men to be hired, after the simplest designs that modern engineering can devise (Ford 1922, 73-74).

Ford accurately surmised that if there was to be a mass-market for automobiles, first-time car buyers would be most of his customers and the most important characteristic of his cars was going to be its price. According to him, other important characteristics were a quality product and customer service for that product (Ford 1922). About service and quality, Ford wrote that . . .

> A manufacturer is not through with his customer when a sale is completed. He has only then started with his customer. In the case of the automobile, the sale of the machine is only something in the nature of an introduction. If the machine does not give service, then it is better for the manufacturer if he never had the introduction, for he will have the worst of all possible advertisements—a dissatisfied customer . . . A man who bought one of our cars was in my opinion entitled to continuous use of that car, and therefore if he had a breakdown of any kind it was our duty to see that his machine was put into shape again; at the earliest possible moment (1922, p. 41).

There was still the matter of designing the model T. In the first five years of the Ford Motor Company, it tried eight different models and various colors. The Ford Motor Company announced in 1909 that it would build only the Model T (Ford 1922, 70). Actually, the model T had five or more body types ranging from two-person coupes to 5-person touring cars, but the basic chassis design (frame, wheels, engine, and controls) remained largely unchanged for almost two decades.

The Ford Motor Company did incredibly well with his Model T for many years. In 1921, it controlled 55% of the very crowded automobile market. By 1923, his unit sales had doubled from two years ago but his share of the market declined due to an even larger increase in unit sales by GM. After 1923, demand for the model T began to drop and never recovered to its peak in 1921 (Federal Trade Commission 1939). Ford's problem was "competition on both a price and quality basis" from other manufacturers (Dalton 1926, 31) who offered more technologically advanced cars and a variety of models for different purposes and budgets.

One reason for Ford's initial success was its new approach to controlling markets. In Henry Ford's own words, he started with the "consumer, and worked backward through the design, and finally arrived at manufacturing" (Ford 1922, 146). In addition to matching mass production with large-scale consumer demand, Ford also pioneered the practice of inventory control, which involved matching production volume to predictions of market demand through information flows from dealers back to the factory (O'Brien 1997). He used these elements of modern marketing when other corporate organizations were still relying on predatory trade, collusion, and vertical integration by internalizing down and upstream capability as ways to control markets. Of course, Ford also used many of these older methods. New methods of systems building usually do not replace old methods, they just add to an organization's repertoire.

However, Henry Ford's assessment of what consumers wanted in a car remained unchanged for too long and became increasingly over simplistic and outdated. New auto buyers in the early 1900s probably did not know what they wanted in the design of a car. Most were very unfamiliar with the technology. However, ownership quickly increased, personal income went up, and a culture of the automobile emerged. There was emerging the beginnings of a complex, modern surface transportation system with the personally owned internal combustion engine as its technical nucleus (Barker 1985; Hugill, 1982), and by 1923 there were 15 million automobile, bus, and truck registrations in the United States (U.S. Census Bureau 1960). Also, many car owners were looking to upgrade to more expensive cars. The direct result for Ford was that price was no longer the most important factor to a great many customers. Power, handling, comfort, style, and status became increasingly important.

Henry Ford changed the automobile industry and the transportation system, but his company was unable to adapt to these changes that itself had set in motion. The stubborn, prideful, authoritarian personality of Ford was a factor. He did not allow for his company to develop the organizational capacity to dynamically respond to these larger changes. However, that common explanation is too simplistic and unsociological. It was very rare to find a company in the early 1900s that could dynamically respond to changing technology and consumer demand. In this regard, the Ford Motor Company was not alone.

However, where Ford failed, General Motors (GM) and other automakers eventually seized the opportunity. They adopted Ford's strategy of linking mass production to the mass market, but went much farther. GM was able to structure its organization into a set of capacities to adapt to changing technology and market demand as well as exert an influence on the pace and direction of it.

GM's marketing strategy included using a highly diversified set of product lines, trying to tailor each of their models to consumer needs and tastes, and actively shaping their customers' needs and tastes to match particular GM automobiles. This strategy can be broken down into a three-fold approach to continually redefining what the perfect automobile was in style and performance for each type of customer and associated that mental image with a specific GM car. *First*, GM offered "a car for every purse and purpose" so that regardless of what a customer needed—a coup or sedan, a car for long trips or running errands—as they "moved up the economic scale, he could move on to a more refined-and more expensive-GM car." In 1926 GM had six different lines of automobiles—Chevrolet with five models, Pontiac with two models, Oldsmobile with six models, Oakland with seven models, Buick with sixteen models, and Cadillac with thirteen models for a total of 50 different models. The prices range with approximately $100 dollar increments from $525 for the cheapest Chevrolet up to $4,485 dollars for the most expensive Cadillac.[24] *Second*, GM decided on yearly model changes: "improvements should be introduced regularly so that each year every GM car would be better than its predecessor would. The customer, in short, should be kept permanently dissatisfied" (Allen 1996, 61, also see McCracken 1998 and Campbell 1992 for a more general discussion of the ratcheting up of demand. *Third*, GM knew that style sold autos. The color and overall look of automobiles mattered a great deal to buyers. Although popular styles were always changing, GM attempted to defined and adapt to these changes. In 1923, GM

[24] This information was compiled from Motor Age by Chandler (1964). Also, it is interesting to compare the GM lines with the lines of the Ford Motor Company which had only two lines in 1926—Ford with seven models that ranged from $260 to $685 and Lincoln (recently purchased by Ford) with nine models that ranged from $4,000 to $5,300 with no models in the middle.

shocked the auto world by offering an auto in egg shell blue, which was the first mass produced auto in a color other than black (Clarke 1999).

Of course, GM was able to pursue this overall marketing strategy because it was developing a set of organizational capabilities to dynamically both shape and respond to technological change in the industry and the market place. These included R&D labs, modern marketing departments, market research, and flexible manufacturing facilities.

In 1920, GM established an R&D lab headed by Charles Kettering that would produce a stream of new inventions and product developments that would continue to make the automobile cheaper, more dependable, and easier to use technology. The lab would be an important driver behind the yearly model changes, and its inventions included high compression engines, leaded fuel, four-wheel brakes, balloon tires, and safety glass. Each R&D project required a substantial up-front investment and no guarantee of success, but by simultaneously investing in a diverse set of R&D projects, GM was able to expect a fairly steady stream of innovations that would allow it to continually improve their product line of automobiles. More to the point, it allowed them to keep control of the market and stay ahead of competitors. GM also researched other transportation technologies, such as two-stroke diesel engines, that allowed GM to diversify into and gain control over other parts of the transportation system (Allen 1996).

A new product design office, which was called the Art and Colour Section, was created in 1927, and became another important force behind new model changes. While engineers designed the engines, wheels, transmission, lights, and doors, the Art and Colour Section determined the overall look of automobiles. By 1941, the section had a staff of 300 individuals and was said to have a direct phone line to Alfred Sloan, the GM president, which reflected the importance that GM management placed on this aspect of product development. GM management knew that style sold autos, but it was much more difficult for them to predict which styles and colors consumers would prefer even a year in the future. To aid design considerations, GM monitored data from dealerships on which colors and styles sold best, which provided short-term design guidance (Clarke 1999).

Because consumer tastes often changed rapidly and unexpectedly, and model changes were always risky. What GM needed to do, according to O. E. Hunt, the Vice President of engineering, was to discover the consumers' underlying beliefs that were behind their tastes. This knowledge could then be used to guide design principles over the longer term. Sales data and consumer research lead them to the design principles of all steel bodies and chassis (as opposed to wood) and longer, streamlined vehicles with a lower profile. This general set of design principles constituted the modern look that dominated the auto industry for decades, but the specific design details still presented much risk and considerable investment in retooling. However, predicting consumer preferences could not be reduced to a science, and competitors would still sometimes catch GM off guard with an exceedingly popular design that would redefine what both GM and customers thought of as stylish (Clarke 1999).

To increase the fit between that of technical inventions and product design and that of market demand, GM created a new office within the company called the Consumer Research Staff to study consumers. The office was directed by Henry Weaver who conducted research in at least the following areas.[25] First, Weaver explored the importance that potential customers placed on auto features such as the V-8 engine and automatic transmission and how much extra they would likely pay for these features. Second, his office researched the customers' impressions and understandings of automobile features so GM could head off complaints or poor sales with customer education or product improvement. Third, they researched the brand loyalty of car owners (Clark 1996).

The manufacturing innovations at GM included the wide use of common parts for the assembly of many different models to keep the unit price down. This allowed GM to capture economies of scope from their diversified product line as well as economies of scale from the shear size of operations (Chandler 1990). Also, instead of using single-purpose machine tools and manufacturing equipment, they developed multipurpose tools and equipment for their manufacturing facilities. When technology changed, they could simply change the molds, jigs, and dies for these pieces of flexible equipment (Raft

1991). When Ford very grudgingly changed production from the Model T to the model A, Ford Motor Company had to completely shut down its entire manufacturing process for an entire year to retool, which was of course at a huge expense. On the other hand, GM had developed the technology and organizational routines to efficiently make yearly model changes at a reasonable expense. Technological change had become a set of routines for them.

GM also spent a considerable amount of money on advertising and public relations to associate in the public's mind an image of GM autos as the most modern, stylish, and technically advanced cars on the market, which included the use of direct mailings and magazine and newspaper advertisements. In an attempt to increase the efficiency of this advertising, Weaver conducted research to determine which periodicals were read by automobile buyers (Raft 1991; Clark 1999).

The major contributions that GM made to system building in the automobile industry were routines for technological change. The investments that GM made in R&D and marketing gave them a substantial degree of control over technological change in their industry and the auto market. They were able to carefully design technology to fit within the sociotechnical system in a way that would both expand and elaborate that system and increase their control over it. With their annual model changes, GM was able to outsell most of its competitors by continually redefining what an automobile was supposed to be and then associating that image with GM cars. This created an additional barrier of entry to new competitors of both scale and scope. R&D, marketing, and yearly model changes required a substantial up front investment that smaller manufacturers could not make. Only two other US automobile manufacturers—Chrysler and Ford—were able to make the necessary investments to seriously compete with GM, and they did so largely by adopting GM strategies. By 1940, the "big three" controlled the large majority of the US automobile market. After WWII, the other smaller manufacturers had all but disappeared.

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[25] Since consumer research is proprietary information, there is incomplete knowledge about how much research was conducted and to what exact use it was put within GM and other firms in the early half of the 20th century (Clarke 1996).

Telephony

The early telephone system was different from the earlier automobile-centered, surface transportation system, and required a different type of research agenda. Although the automobile was highly systematic, it was rather loosely coupled to the demand-side of the system. The telephone system was an assembly of very tightly coupled parts. If the telephone as the core technology of the system was to deliver quality service, it was dependent on the creation of a standardized, highly integrated, nationwide, technical infrastructure. This system consisted of a set of complicated, highly technical electrical and mechanical parts that needed to be precisely coupled together if the network was to provide quality service, or function at all. Conversely, most parts of the surface transportation system did not need to be standardized. While roads needed to be integrated into a larger network for motorists to get from one road to another, the actual interfacing of these assorted roads is technically very simple. Because of these limited needs for integration and standardization, a centralized research and development program was not needed. Most problems could be handled by their respective organizations in a decentralized manner. However, as telephony evolved, many problems arose in various parts of the system that were tightly coupled to other parts which also had serious problems. A solution to one part of the system could cause an even worse problem in another, or potentially a single solution could be found that could solve all the problems. Much more so than R&D in the auto industry, it was important to have a centralized R&D lab in the telephone system that could identify the most serious technical problems and find a solution that made sense for the system as a whole.

However, the early telephony developed through decentralized lines and the result was a highly fragmented system by the 1900s. The lack of a standardized, integrated, national network was a source of poor telephone service, made long-distance service impossible for many parts of the country, and interfered with the development of telephony. This decentralization was largely because a large number of independent telephone companies focused on developing the lucrative but geographically isolated urban markets. Thus, local telephone exchanges tended to develop independent from one another with different kinds of equipment and wires. This was even the case for many of the local telephone exchanges that were owned by the same company (Galambos 1992, 3; Reich 1985).

For standardization and integration to take place, more centralization was needed. A large competitive advantage would exist for any firm that was able to gain centralized control of a significant number of local networks and then standardize and integrate them into a national system to provide affordable, high quality local and long distance. An integrated national system could also be used as a powerful weapon against smaller competitors who could be denied connection to the larger system, and who could not afford to establish their own (Reich 1985; Mueller 1997 and Galambos 1992).

It was, of course, AT&T that would build this integrated nationwide system, which was founded in 1877 as the Bell Telephone Company. The company “enjoyed a relatively secure patent monopoly” until 1894, which allowed it to control most of the market and accumulate a large number of local telephone services and even link some together. While the Bell system did grow and develop during this time, it did so much more from monopoly power than from innovation. In sum, Bell’s strategy was quite conservative. Its stockholders appear to have placed a higher priority on Bell Telephone as a stable source of personal income than on making long-term investments in its system. It relied on patent rights to hold back the constant challenges from independents, and it focused its investment dollars on providing local telephone service to lucrative urban markets instead of aggressively developing a national system (Galambos 1992, 3; Reich 1985).

When Alexander Graham Bell’s original patents ran out in 1894, Bell Telephone was hit by a wave of competition for the first time. Although this was hard on profits, the Bell system grew from about 300,000 phones in 1895 to almost 2,300,000 in 1905 due to the rising demand for phone service. However, the company “had overextended itself financially” and it had not “succeeded either in blocking the progress of the independents or in maintaining a particularly high quality of service.” About 50% of the market was controlled by independents (Galambos 1992, 3 Reich 1985).

Early Bell Telephone had been overly reliant on its patents to hold off competition, and had not adequately invested in the organizational and technical components of a telecommunication system that could fend off competition by other means. In terms of its strategy, Bell Telephone also existed as a holding company, which was an organizational form ill suited to coordinating the parts of a complex, constantly expanding and evolving sociotechnical system that needed to be tightly coupled to function properly. Most of the constituent companies were local firms that ran the local telephone exchanges. One of these companies was Western Electric that manufactured Bell telephones and equipment, and it eventually became the home of Bell's R&D lab.

To be fair, a corporate organization with a well-developed R&D lab and sophisticated capacities for system building was rare for the era. Nevertheless, Bell did make some inventions that apparently helped regain its patent advantage (Hughes 1989; Reich 1985), most of its R&D was quite conservative. It remained heavily dependent on buying patents from independent labs, making improvements, and incorporating these inventions into the telephone system for small, incremental improvements in telephone service. Western Electric and its Engineering Department provided assistance (Galambos 1992).

AT&T, which had changed its name from Bell Telephone, was in serious financial trouble in the early 1900s. Its investments had not generated sufficient revenue, and it was having difficulty selling its bonds and stock. In 1907, AT&T's largest stockowner, the banker J. P. Morgan, took control of the company and changed its management. He installed Theodore Vail as the chief executive officer who had worked for the company when it was Bell Telephone (Galambos 1992).

Immediately, Vail realized that the company badly needed a new strategy. He intended to create a well-integrated, national telecommunication network that could deliver long distance service over a much larger area and local service. Vail called this goal "One System, One Policy, Universal Service." He claimed that no group of independent companies could provide the same service that Bell could with such a system (cited in Galambos 1992, 4).

However, the company did not have all the organizational capacities that it needed to engage in successful system building. In the next five years or more, Vail undertook three closely related, largely simultaneous attempts to develop three crucial organizational capacities for system building. The capacity to better control the process of technical invention was, of course, one of these. Another was strengthening the company's ability to generate financial resources to flexibly use for system building. Also, Vail developed a strong central office to coordinate the various parts of AT&T and the larger sociotechnical system.

Vail immediately took steps to create a source of investment capital to use for system building. He stated in 1908 that he wanted to accumulate "enough surplus to provide for and make possible any change of plant or equipment made desirable, if not necessary, by the evolution and development of business" (cited in Galambos 1992). However, because he was faced with a question of solvency for the firm, one of the steps he took was to cut expenses. J.P. Morgan told Vail "no expenditures should be entered upon in the near future, except such as are absolutely necessary, no matter what the prospective profits" (cited in Reich 1985, 151). Vail also allocated investment capital more carefully. He stayed away from the rural markets into which the company had previously ventured and focused on the more profitable urban markets. Also, for the first time, independent companies were allowed to purchase AT&T telephones and apparatuses, and subsidiaries were charged 4.5% of their gross revenue to finance the central administration of the Bell system including R&D (Galambos 1992).

In 1911, Vail stepped up the "Research Branch" within the Engineering Department to engage in more basic research and invention in addition to merely the final stages of innovation. This lab became a tremendous asset for AT&T, and it grew to at least forty people by 1915 with seven Ph.D. scientists. The Research Branch gave AT&T substantially more control over technological changes in telephony. The Engineering Department identified points of resistance in the expanding technical network of telephones, wires, transformers, and switches. Then the top management, who carefully controlled the research agenda, directed the Research Branch to focus on exactly those points. This gave AT&T the greatly enhanced ability to create and fit new technology into the system in ways that could predictably improve, expand, and elaborate that system. The Research Branch went on to generate a number of inventions that became core technologies of the expanding Bell system (Reich 1985; Galambos 1992).

However, the decentralized nature of the AT&T holding company was an impediment to the efforts of the central office to integrate technology into its constituent companies and thus build a nation-wide, integrated telephone system with modern technology. For a system as heavily dependent on tightly coupled technical components, it was critical to have a strong central office that could coordinate the system building process. This included the ability of the central office to standardize and modernize the technical components of the Bell system. However, when the central office tried to introduce new technology into the Bell system and standardize its use, it often experienced significant resistance from its subsidiaries. AT&T's chief engineer in 1906 commented that in many of its subsidiaries, the engineers would "disregard recommendations and specifications" and did "not operate to the best interests of their own company nor of the business at large" (cited in Galambos 1992, 3). To consolidate control, Vail increased AT&T's financial stake in its operating companies until it had majority ownership, and then consolidated them into functional departments that could be centrally controlled (Galambos 1992).

The central office gained control over the Research Branch and used financial controls over it to match its R&D projects to that of the company's overall strategy to create an integrated, nationwide telephone network. Individual researchers had little freedom to pursue their own interests (Carty 1924, 4). Most of the carefully chosen research efforts were to improve the technical viability of long distance service and handling the increasing volume of telephone calls. In the very early Bell system, long distance communication was limited because transmission signals lost their strength over short stretches of wire. In 1899, the Engineering Department came up with the idea of using loaded coils that would allow transmission distances to be extended up to 1,500 miles, but delays by AT&T patent attorneys allowed a university professor to patent the device. The company then had to pay a large sum for rights to use loaded coils. However, coast-to-coast service still eluded AT&T (Reich 1985).

In 1909, AT&T's chief engineer publicly declared that AT&T would demonstrate a transcontinental telephone line by 1914. Accordingly, the company substantially increased their investment in R&D. Through basic research to understand the physics behind the audion—an earlier invention by independent inventor Lee de Forest—the Research Branch invented the electronic repeater. With this invention, AT&T could amplify signals for greater distances. In 1915, only a year later than planned, AT&T established the first transnational transmission and thus solved the most important barrier to an integrated, nation-wide telephone network. To allow higher volume traffic in the profitable urban markets, the Research Branch developed automatic switching mechanisms and wires that could carry a larger number of transmission signals. Other inventions include the French phone with a more convenient hand-set and chemically treated telephone poles (Reich 1985; Galambos 1992).

When introducing new inventions, a set of routines was followed to insure a good fit between the existing system and new technology. Before new technologies were fitted into the entire system, trial installations were used to test performance under real conditions and to predict component failures and unforeseen interactions. Also, it carefully timed the introduction of new technology to avoid making technology obsolete before it sufficiently depreciated in value (Galambos 1992; Bell Laboratories 1975).

Other routines were used to insure that AT&T could control its inventions through patent rights. The activities of the patent office were well integrated with R&D activities through formal and informal routines that coordinated the two. Researchers were expected to keep laboratory notes of experimentation and to send memorandums to the Patent Department summarizing their research and its contribution to AT&T. Once patents were drawn up, they were sent back to the Research Branch for comments, suggestions, and approval. Also, lawyers would scan the Official Patent Gazette for related inventions to suggest additional directions that could yield patentable inventions (Reich 1985).

Chemical Industry: Nylon

Not all important system arrangements are geared toward products or services for end-product consumers. Many are organized for manufacturing inputs for industry customers, and corporate organizations also use R&D and marketing to exert control over technological change amidst these system arrangements. A specific example is DuPont Chemical in the 1930s undertaking an R&D project to develop the world's first truly synthetic polymer fiber that was commercially viable in the textile industry.[26] This synthetic polymer was nylon, and it is an important example for a few reasons.

The invention and development of nylon was unprecedented. It was the first or one of the first major instances of a corporate R&D laboratory generating an entirely new, technically complex, basic invention and developing a set of production technologies for it as a major new product (Hounshell and Smith 1985). As previously mentioned, essentially all corporate R&D projects of the era had started with the basic inventions of others and merely developed them into marketable products. However, the basic invention of nylon was made by DuPont and its development into a marketable product represented a fairly radical departure from the existing semi-synthetic, cellulose-based, production technology that nylon made obsolete. Also, DuPont did not undertake this R&D project to defend its market share. Instead, it did so to gain access to new markets that were occupied by natural fibers.

To understand the how and why DuPont was one of the first corporate organizations to build the capacities to invent and develop a highly technical, major, new technology when most other firms were decades away from a similar project, a few things about its history are relevant. In the late 1800s, DuPont was like most manufacturing firms. It was narrowly focused on one or two products, and it existed as a randomly structured assortment of firms within a holding company. It had started out as an explosives manufacturer, and by the early 1900s it had gained almost complete dominance of the market. It had done so by purchasing other explosives companies and placing them within its larger holding company that grew to have a substantial degree of monopoly power over the black powder, dynamite, and smokeless powder markets. During times of war, it made enormous profits, but during times of peace the company was financially burdened with large amounts of idle capital and personnel.

Because of this cyclic nature of the explosives market and, also, government enforcement of anti-trust legislation, DuPont went looking for other products to sell that would provide a more stable use of its production capabilities. Most explosives in the 19th and 20th centuries were cellulose-based chemicals,

[26] Rayon had been manufactured and sold by other companies since 1908 and by DuPont since 1920. However, this polymer is not a true synthetic because it is made by treating cellulose—a natural polymer—with aqueous caustic

and DuPont's strategy was to diversify into other cellulose-based products. This approach included internally developing from scratch the capacity to manufacture and sell inputs into these other product markets. However, DuPont found, as most firms did, that it was easier and less risky to enter these other markets by purchasing existing firms that already manufactured and sold in these markets than to develop the needed capacities internally. Through acquiring other firms, DuPont entered markets for other cellulose products such as viscose, celluloid, celluloid acetate, nitrocellulose film, artificial leather, paints, and lacquers by the early 1920s (Hounshell and Smith 1988).

The firms that DuPont acquired tended to be young companies or those with problems in their manufacturing, research, and marketing capacities. Thus, DuPont used its increasingly sophisticated R&D labs and other organizational capacities in cellulose-based technology to increase the competitiveness of these newly acquired firms. Not only did DuPont improve existing products of these firms, but it also was even more successful at developing new products to add to the existing product lines of these acquired companies. By 1931 it had acquired or internally developed the capacity to make a number of very important products, which included artificial dyes, Freon, ammonia, photographic film, rayon, cellophane, and electrochemicals (Hounshell and Smith 1988; Chandler 1962; 1990).

There were also occasions when DuPont foresaw the potential for entirely new products that no existing firm yet manufactured. One of these was synthetic polymers to be used as replacements for natural and semi-synthetic fibers. In such instances, the company had no choice but to use risky, long-term, expensive R&D projects to internally build such capacities from scratch. DuPont engaged in basic research into synthetic polymers that led to a successful development project to produce a commercially viable synthetic fiber for use in women's stockings. This synthetic polymer, initially referred to as polymer 66, was eventually named Nylon (Hounshell and Smith 1988).

The basic research program into polymers was started by the Chemical Department in the 1920s and generated the basic science that structured the search and selection routines to find a polymer suitable for commercial development. This science included the types of chemicals that formed polymers, how to

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soda and carbon disulfide, and then neutralizing the base with an acid solution (Hounshell and Smith 1988).

control the reaction in the formation of polymers, and a theoretical understanding of the chemical and physical properties that polymers of each family of chemicals were likely to have. The basic research project also developed techniques to scientifically quantify the properties of fibers which included tensile strength, fatigue resistance, melting point, and resistance to water (Hounshell and Smith 1988).

From this theoretical framework that emerged to understand polymers, lab managers were able to construct laboratory routines that would align their R&D project with DuPont's organizational goal of finding and developing a polymer with high tensile strength, fatigue resistance, high melting point, and water resistance. That is to say, management controlled the process of invention by routinizing it. Although it is an over simplification, much of the remaining laboratory work was to find the best candidate to develop into a commercially viable synthetic fiber. Technicians perform the mundane experiments to sort out empirical details of which remaining polymers had the desired properties. This consisted of synthesizing each polymer and then running each of them through a battery of tests to see if it any had commercial potential (Hounshell and Smith 1988).

After synthesizing hundreds of chemicals into various polymers and then testing each for their chemical and physical properties, the Chemical Department's polymer research team synthesized a polymer of adipic acid and hexamethylene diamide. It appeared to have the characteristics that they were seeking, and they temporarily called it polymer 66. In July 1935, they chose this polymer for commercial development (Hounshell and Smith 1988; Chandler 1990).

However, for what market should they try to develop polymer 66? Enthusiastic researchers saw polymer 66 "replacing, among other things, cellophane, photographic film, leather, and wool" and silk. However, it was not practical to pursue all of them in a single R&D project because each requires different technical specifications and systems requirements. DuPont managers used "considerable restraint" by only targeting the market for silk and picking an even more specific market, silk stockings (Hounshell and Smith 1988, 257). While DuPont was hoping to eventually develop all these products, it knew that system building was an incremental process and each step needed to be a focused effort.

That aside, why did the managers of the Chemical Department choose silk stockings as their single target? In the male dominated science and engineering professions of the 1930s, it is perhaps surprising that the managers and researchers would have chosen women's full fashion hosiery as the first market for their polymer instead of a manlier product, such as leather or even wool. However, it appears that the department managers were quite pragmatic, as they needed to be if they were to succeed at their complex system building endeavor. However, the textile industry was a very well established, large, lucrative market. Both wool and silk were reasonable possibilities for target markets, but wool had a disadvantage from a market point of view. Although there was a larger market for wool, this natural fiber "sold for less that half of the price of silk, and DuPont doubted" that their synthetic fiber could compete (p. 264). Wool also had a problem from a development point of view. Wool garments take a great deal more fiber to make than stockings. To test polymer 66 as a wool substitute, DuPont would have had to make a larger up front investment to build a bigger pilot plant to make enough polymer 66 to adequately test it as a wool substitute. Silk stockings, on the other hand, required very little fiber. Thus, lab managers decided to pursue polymer 66 as a silk substitute for women's stockings.

Also, DuPont already had an investment in infrastructures to manufacture cellophane, film, and artificial leather from cellulose based semi-synthetic fibers. If polymer 66 would have immediately been developed to compete in these markets, DuPont would have been competing with themselves. However, cellulose based fibers such as Rayon did not make a high quality full fashion hosiery, which was an additional reason why the R&D project decided to pursue the silk stockings as a market use for polymer 66 (Hounshell and Smith 1988, 261).

After these deliberations, DuPont had defined its specific problem: how to develop polymer 66 into a fiber that is commercially viable as a silk substitute. Then, a strategy was needed to solve it. The Chemical Department constructed a well thought out three-stage R&D plan to develop the needed manufacturing and marketing capacity and simultaneously explore the likelihood of nylon being a commercial success as a silk substitute.

The R&D strategy used by DuPont is an example of text-book quality about how to efficiently and effectively integrate a new invention into a sociotechnical system, and also realistic in regard to the type of problems that can be encountered and what it takes to solve them. *First*, DuPont attempted to develop the capacity to synthesize polymer 66 and make it into a fiber at a price competitive with silk fibers. The most immediate challenge and a barrier to cost effective production was finding an affordable source of hexamethylene diamide, which was not available on the market in significant quantities nor were the chemicals to readily available to synthesize it. However, DuPont's ammonia department had experience working with both catalysts and high pressure synthesis that were necessary to make hexamethylene diamide.[27] After tribulations and experimentation, a process was found to make the diamide.

Developing the capacity to produce this diamide had to be the first step in the R&D project. Without an affordable source of substantial quantities of hexamethylene diamide, other steps could not be affordably conducted on a scale that would generate useful conclusions about overall viability. DuPont could not have manufactured enough diamide to develop a batch process of synthesizing polymer 66. Without sufficient quantities of polymer 66, tests could not be conducted on spinning techniques, which was necessary before knitting and dying techniques could be developed.

The point is that, for systematic innovations in tightly coupled parts of sociotechnical systems, system building has less chance of succeeding if it proceeds in helter skelter fashion. Order and coordination are important. However, this does *not* mean that system building must follow a rigid, linear process. Some steps can proceed simultaneously, but an R&D project should not advance from one step to the next unless the innovation in the first step can meet a minimum set of performance criteria that are needed for the next step to have a good chance of succeeding at a reasonable expense. This was very close to how polymer 66 was developed into a successful product. In general, the primary criterion for moving to the next step was to produce enough material to begin that next step and, also, to make reasonably sure that each step could be cost-effective when scaling up for mass production.

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[27] This fact had also influenced the choice to use polymer 66 instead of another.

Once several pounds of the adipic acid and the diamide were available, DuPont proceeded to the second part of the first stage of development. It needed to develop methods of producing a polymer that could be made into a high quality, uniform, continuous fiber. There were two problems. All molecules of the polymer needed to be very close to the same length, which meant the reaction between adipic acid and the diamide had to be stopped at the same moment in the batch process. Eventually it was found that this could be accomplished by the addition of acetic acid—"another simple solution that required considerable time and effort to be discovered" (Hounshell and Smith 1988, 263).

The most difficult problem was developing a technique to spin polymer 66 into a continuous fiber—the third part of the first stage. Existing mechanical methods of spinning silk or wool would not work. Both solution and melt spinning were considered. However, the managers again put all their "eggs in one basket" and decided that they would develop melt spinning because it used solvents that were dangerous and expensive to recover. Instead, molten polymer 66 was to be extruded through small holes to produce a fiber that hardens at room temperature. Unfortunately, the fibers kept breaking inside the apparatus for unknown reasons, and commercial viable spinning had to be continuous (Hounshell and Smith 1988).[28]

In the summer of 1936, the Rayon Department stated that the new fiber was "a high quality yarn superior to natural silk" that likely would have a large market at $2.00 per lb. As yarn, polymer 66 could be produced for $0.80 per lb. if melt spinning could be perfected. However, for over two years, this problem persisted, and management was very worried that they would have to use the more expensive solution technique. Even though problems with melt spinning continued, the technique was producing enough fiber to start the *second stage* of development (Hounshell and Smith 1988, 264).

Second, the R&D project began to develop a technique to knit and dye polymer 66 to the specifications needed by the target market. For this, they expanded their production "capacity from 2 to 100 pounds per day to improve the process and provide material for extensive testing" (Hounshell and

[28] Silk and wool were naturally fibrous and could thus be spun into a continuous process through mechanical means. When Polymer 66 was synthesized, however, it was an amorphous lump of plastic--completely non-fibrous. DuPont had been manufacturing Rayon with the solution technique was thus knowledgeable of its shortcomings as a technique to spin amorphous plastic into fiber.

Smith 1988). DuPont did not intend to develop their own capacity to knit or dye yarn, so a DuPont scientist took a few skeins of yarn to the Union Manufacturing Company where testing began on knitting and dying. The plant had trouble with polymer 66 at nearly every stage. "It does not come off the spools properly; it snagged on the knitting machines; and dying it looked like a wrinkled mess that had 'a not too pleasant gray color roughly approximating gun metal.'" Undaunted, the scientist "attributed these difficulties to inexperience with a new material" (Hounshell and Smith 1988, 266).

In addition, the problem with melt spinning had not yet been solved, and the assistant project manager was becoming pessimistic. However, considerable resources continued to be spent on making the technique workable. With a barrage of experts attacking this problem and further development of the knitting and dying processes, most of the serious problems were solved by fall 1937. The problem with melt spinning was diagnosed as gas bubbles clogging the spinneret, which was solved by keeping the molten polymer under pressure (Hounshell and Smith 1988).

By Christmas, "fifty-six hosiery and lingerie garments were distributed to the wives of the men working on the nylon project." The garments were viewed as very durable, but "wrinkled easily and were too lustrous and slippery" (p. 267). One project manager commented, "We are not out of the woods, but think we can see our way clear" and that within six months most of the remaining problems could be solved (Hounshell and Smith 1988).

DuPont still did not know how polymer 66 would fair in a real market. Nor had they any experience with a full-scale production facility. Before the company built a commercial plant, they decided to experiment with a middle size plant. The R&D project began the *third* phase of development when in January 1938 the executive committee authorized the construction of a pilot plant that was one-tenth of a full plant. It would test their mass production techniques and specifically if the various process elements could consistently produce a high-quality, uniform yarn. Also, the one-tenth size plant was needed to make enough yarn for more market testing (Hounshell and Smith 1988).

However, one remaining problem looked increasingly serious. The R&D team could not find an adequate "sizing" (i.e. a coating) for the fibers. Silk fibers have a natural sizing that acts as protection from handling during the textile process. However, after a last minute intensive search, they found an appropriate sizing just before the new pilot plant went into production (Hounshell and Smith 1988).

Even before the third phase started, DuPont had been working on ways to market polymer 66. The Rayon Department already had marketing capabilities and relations with the textile industry, which had already helped the R&D project test the knitting and dying processes at Union Manufacturing. However, DuPont still needed a catchy name with a simple punctuation. A committee was set up to make the decision and it received over four hundred suggestions. Some of the final ideas were duparooh, delawear, neosheen, nuray, norun, nuron, nulon, nilon, and, then eventually, nylon (Hounshell and Smith 1988).

DuPont tried to keep nylon a secret but word leaked, and contributed to media attention. In a calculated move for even more media, a renowned chemist at DuPont, Charles Stine, made the official announcement about nylon stockings to 3,000 women's club members at the New York World's Fair site as part of the *New York Herald Tribune's* Eighth Annual Forum on Current Problems. Stine said,

> . . . I am making the first announcement of a brand new chemical textile fiber. . . the first man-made organic textile fiber wholly prepared from new materials from the mineral kingdom. I refer to the fiber produced from nylon . . . Though wholly fabricated form such common raw material as coal, water, and air, nylon can be fashioned into filaments as strong as steel, as fine as a spiders web, yet more elastic than any of the common natural fibers (Stine cited in Hounshell and Smith 1988, 270).

The audience thought "strong as steel" meant indestructible, and Stine received a burst of applause. Media attention contributed to the misperception. Attempting to lower expectations to a realistic level, the sales promotion manager became known as the sales demotion manager (Hounshell and Smith 1988).

When nylon was released to the market in May 1940, DuPont priced it at 10% higher than silk. Sales were brisk, and by the end of the first year, a large majority of its R&D investment had been paid off. In the following year, DuPont sold $25 million worth of nylon for a return on its investment of 30%. In less than two years, DuPont had "captured over 30 percent of the full-fashion hosiery market." During much of that period, demand out-paced supply (Hounshell and Smith 1988).

DuPont achieved commercial success for nylon with unprecedented speed. In only five years, it put in place an almost entirely new sociotechnological infrastructure to manufacture and sell nylon that could be used in the textile industry. In addition, the company obtained patent rights that were “impregnable” for its near future since no other company was even close to having the organizational capacities to produce and sell this synthetic fiber or to develop a competing fiber (Hounshell and Smith 1988). However, nothing should give the reader the impression that the R&D project was easy or that success was certain. The project encountered numerous problems, and some had seemed unsolvable. That the project was successful in such a short time is a testament to the system-building capacities of DuPont.

In hindsight, the development of nylon appears to have been “the solution of thousands of small problems. . . [and generally] the development of nylon proceeded in a systematic and orderly manner . . . but this kind of engineering could begin only after big decisions were made about how nylon should be manufactured.” This included the pursuit of melt spinning and women’s stockings as the target market. After thoroughly studying its options, DuPont repeatedly “put all its eggs in one basket.” (Hounshell and Smith 1988, 261). When it encountered a significant problem, it was able to focus a large amount of resources on solving it and did so with confidence because it had enough theoretical knowledge and experience with similar problems to understand what was likely solvable and what was not.

To summarize why DuPont was an effective system builder: Although Hounshell and Smith (1988) used different terms, they essentially wrote that DuPont’s success with nylon had much to do with its organizational capacities for system building. *First*, DuPont had a world-class R&D facility and staff with enough experience and knowledge in the area being researched to understand what was likely possible and what was not. *Second,* through its vertically and horizontally integrated organizational structure, it had access to the necessary production and marketing capabilities to develop, produce, and sell a complex, systematic, technological innovation such as nylon. *Third*, the sales of existing products lines had generated enough financial revenue that could be used to fund long-term R&D projects.

Although the R&D cost was 4.3 million in 1930 dollars,[29] it was not a significant burden for DuPont. *Lastly*, DuPont had a strong central office to strategically plan and coordinate system-building activities. Although the top executives of DuPont were not very involved in the project, the director of the nylon R&D project had an office located within the central office and had its clout behind him. If they needed something from another part of the firm, the director usually got it (Hounshell and Smith 1988a).

However, the success of DuPont was also due to the approach that it took to system building, which can be viewed as a "how to" lesson in efficiency and effectiveness. Moreover, it can be used as a bench mark from which to evaluate the organizational effectiveness of other system builders. It is also important that DuPont chose a specific, well-defined problem, and R&D staff took the time and effort to thoroughly study their research problem and likely solutions before actually developing nylon. In other words, they planned well. In addition, they had the patience not to move to the next stage of R&D until the problems in the previous stage had usually been solved. Because of this, they were able to ratchet up their production of nylon from lab experiments to full production in a quick and efficient manner.

Whole-Product Design and Standardization

The emergence of professionally staffed, centralized R&D units within industrial corporate organizations gave rise to a whole new way of thinking about product design. Top managers began to take a much more holistic perspective, and they devoted their firms to *whole-product* design. They became interested in the full range of factors that could affect the market success of a product and that must be considered in product design. These factors were essentially a fairly complete list of the major parts of the sociotechnical system and included the availability of components and materials from down-stream suppliers, existing manufacturing capabilities, patent rights, changing technology, distribution, competition, and market demand (Meikle 1979; Fligstein 1990).

Managers realized that their products were actually a set of integrated parts that needed to be integrated into the larger system. Both types of integration were crucial to designing a successful product.

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[29] This does not include the DuPont basic science research into polymers.

They saw that one of the best ways to increase profit was by controlling as many of the interactions between a product and the larger sociotechnical system as possible. However, they also learned that one part of a system could not be optimized in isolation from the rest. A change in one part could have either positive or negative effects on other factors. R&D staff had to look for designs that would address many problems at one time, and this usually took a number of iterations of designing and testing prototypes.

Whole-product design also went hand-in-hand with standardization. Because whole-product design was a time-consuming and expensive process, it was only justified if a product could be mass produced. Thus the making and selling of design-intensive products shifted economies of scale even more toward product standardization and mass production, and took even more discretion away from middle and lower management and from laborers over how they would make products. Despite the large expense and resistance within corporate organizations to standardization (Brown 2000), industrial corporate organizations usually ended up making a cheaper, more consistent, higher quality product that generated a more predictable and favorable response from consumers. This also tended to drive out small competitors that could not afford expensive R&D products, which created additional barriers to entering an industry for new firms (Rosenbloom 1993; Fligstein 1990).

Whole-product design and standardization became common place among companies that mass produced complex, technological items. However, not all industries used these practices, and nor did all firms within a particular industry. The adoption of whole product design and standardization appears to follow the use of vertical and horizontal integration, sophisticated management structures, and R&D units. One of the industries that has been extremely slow to adopt these organizational innovations as well as whole-product design and standardization was the residential housing industry, which are defining characteristics of the industry that we will discuss in later chapters.

The Product Diversification Movement

As mentioned, one of the primary uses of R&D labs was to diversify a firm's product mix. In the 1900s and 10s, corporate organizations such as DuPont, General Electric, and AT&T demonstrated the value of R&D and marketing to control technological change and develop new products. In the 20s and 30s, other firms followed their lead, such as GM. The use of marketing and R&D to diversify their products and product lines continued into the 40s and 50s and has since become an institution of the corporate world. Diversification into similar products very often resulted in synergies that reduced costs of production and increased profit (Chandler 1962; 1990; Fligstein 1990; Berry 1975).

R&D units allowed companies to diversify from manufacturing one or two products in a single product line to manufacturing a wide range of products in numerous, often closely related product lines. Although a few firms such as AT&T used their R&D capability to build a sociotechnical system to deliver a few closely related services, most corporate organizations used R&D and marketing to find new markets for existing products and to develop entirely new products (Fligstein 1990; Pavitt 1992).

DuPont, as discussed, is a good example. It diversified from black powder into dynamite, smokeless powder, and other explosives through both acquiring other firms and R&D. Most frequently it entered new product lines through acquisition and then used R&D and marketing to expand and improve the product lines of the acquired firms. By 1921, it was making products in six different product lines—explosives, dyestuffs, artificial leathers, celluloid films and plastics, and paints, varnishes, and lacquers. For each, DuPont engaged continually in product development (Hounshell 1988). GM did similar with its diversified line of automobiles (Fligstein 1990).

DuPont and many other corporate organizations discovered the strategy of diversification as a new means of controlling the market, generating organizational growth, and spreading out its risk and profits among a diverse set of products. Companies that followed a diversification strategy within the same product line or diversified into closely related product lines tended to be more successful in all three measures of growth in assets, sales, and profit in most decades from 1919 to 1969 (Fligstein 1990).

This growth was driven primarily through the coordinated use of marketing and R&D capabilities. By 1931, more than 1,600 companies reported that they had industrial R&D laboratories or departments, which employed a total of 33,000 people (Reich 1985). This represents of a substantial portion of US corporate organizations that were trying to control technology through internal R&D capabilities.

However, before WWII, the main task of corporate R&D was to commercialize the products that were usually invented by someone else. After WWII, the chemical, food, oil, and rubber industries greatly increased investment in basic research to gain better control over the sources of the basic inventions it had been purchasing from independents and universities. The pressure to keep ahead of the invention game led to even more fundamental research among corporate organizations, and over time invention came to rival development within R&D labs (Chandler 1990). This spelled the demise of independent inventors. By 1946 the independents only accounted for 6.9% of all employed scientists (Mowery 1983 cited in Teece 1998b). By 1970, there were extremely few stand-alone facilities (Teece 1988b).

To exert more control over how customers react to new and existing products, advertising expenditures also increased three fold from $500 million in 1921 to $1.5 billion in 1927 (Copeland cited in Fligstein 1990), and again to $3.2 billion and close to $10 billion in 1956 (Business Week cited in Fligstein 1990). However, even as this was happening, advertising executives generally became subordinate to the heads of the newly formed marketing departments. Marketing departments were often organized into sales, market research, advertising, and new product development offices. Advertising was only one tool used by marketers and was nothing very new, but it was increasingly recognized as a very important investment that often needed to be made just as into equipment or intellectual property rights (Fortune 1956 cited in Fligstein 1990).

Market departments gained popularity in the early 1920s and conducted research on the characteristics of demand and forecasted the sales of new products. Informed with such data, marketing departments would shape the development of new products, and it would oversee efforts to continually improve them and construct advertising campaigns to let customers know of these improvements (Fligstein 1990). About $10 million was spent per year on market research before WWII, and $50 million was conducted in 1947 (Fortune cited in Fligstein 1990). In the same year, 44.6% of the member firms of the National Association of Manufacturers with more than $5 million in annual sales indicated that they had market research departments (Dooley et al. cited in Fligstein 1990).

As mentioned, mergers and acquisitions were also an important tool that allowed corporate organizations to diversify their products and product lines. Thus, it is not surprising that "30.4% of the mergers in the 1920s contained a substantial amount of product-related diversification" (Fligstein 1990, 127).

However, what prompted this new wave of corporate organizations to use marketing, R&D, and mergers to diversify their product mix? It appears that it was some of the same reasons as it was for early corporate leaders. They saw that their profits or even survival was threatened by quickly changing technology and demand, and that their own set of organizational capabilities could not substantially shape these changes to their advantage or easily adapt to them. To address these problems, they mimicked earlier corporate leaders—such as GE, DuPont, AT&T, and to a degree Ford—who demonstrated that it was possible to regain control of an organization's future through diversification fueled by marketing and R&D (Fligstein 1990).

In addition, corporate organizations were hitting the limits of the effectiveness of traditional means of system building. Fligstein (1990) places heavy emphasis on the federal government starting to again vigorously enforce anti-trust legislation in the progressive era (1900-1916). Going into the 1920s, this had curtailed the perceived and real effectiveness of using mergers to form monopolies or engage in collusion and thus control markets. However, developing and patenting new technology and then marketing it was a new strategy. They could use these to diversify and expand without attracting too much attention from the Federal government, but if they captured too much market share they still risked scrutiny.

The great depression was also a factor. Traditional forms of control and system building allowed firms few means to address the drop in demand for their products. "Managers reacted to stagnant or decreasing revenues by finding new opportunities for their business. While diversification began in the marketing revolution of the 1920s, the business conditions of the Depression provide the stimulus for many additional firms to diversify." Even during the Depression, most firms that diversified their strategy were able to retain a healthy profit or even experience growth (Fligstein 1990, 151).

Increased Strategic Capacity for Planning and Central Coordination

The product diversification movement led to fundamental changes in how corporate organizations were internally structured. Simply stated, the centralized decision-making of the functional form of organizations could not cope with the administrative challenges of trying to coordinate the manufacturing and selling of a broadly diversified set of products. This led to a restructuring of the corporate organization to decentralize decision making for day-to-day operational decisions, which freed up the central office to organize itself in terms of *strategic capacity* for strategic planning, evaluation, and oversight of system building and other activities. The resulting corporate form was termed the multidivisional form of organization. This multidivisional-form and its strategic central office, vertical integration, and centrally controlled research labs contained a powerful and sophisticated set of organizational capacities. This is the type of organization that was given the acronym of SMVRCO in Chapter 1.

For even a single product, it was a complex task to oversee and coordinate the flow of inputs through a firm—from that of purchasing, to manufacturing, to distribution, and then to sales, as well as overseeing the auxiliary departments such as R&D, marketing, accounting, personnel, and legal affairs. When firms diversified into dozens of related and unrelated products, this became unmanageable for many central offices. As firms diversified into the production and sale of a wide range of products in numerous and sometimes very different product lines, the combined task of overseeing, coordinating, and allocating resources among departments overwhelmed the central office. Also, it was awkward for department heads of manufacturing to have to coordinate the production of quite very different products ranging from dynamite to photographic film (Chandler 1962; 1990; Fligstein 1990).

The central office usually included a president with one or two assistants, and sometimes the chairmen of the board and perhaps his vice presidents who were each in charge of a functional department. The latter were usually very occupied and often overwhelmed with managing the numerous product lines of their functional department and had little or no time to consider the organization as a whole (Chandler 1962). In addition, the top executives in these diversified but still centralized firms tended to have a background in the manufacturing of only one of the product lines. They were specialists, not generalists, and did not have the breadth of experience and knowledge to understand the needs of other functional departments or the organization as a whole (Chandler 1962; Fligstein 1990).

The solution was, as mentioned, to decentralize day to day decision making, reorganizing the firm into product divisions that each had their own set of purchasing, manufacturing, and marketing departments, and often other departments as well. The exact path taken by firms and their final structure, of course, did vary by circumstances and internal power struggles. The multidivisional form consisted of a central office "to administer the enterprise as a whole" and "divisional offices to administer each of the major product lines." Each division contained its own manufacturing, distribution, marketing, accounting, and R&D departments. This amounted to each division having the capability to operate as its own corporate organization, and it did do so almost completely when it came to day-to-day operations and but less so when it came to strategic decisions (Chandler 1990, 449).

Each division chief was fully responsible for the "division's performance and profits," and the central office gave him full authority over a complete set of organizational capabilities to accomplish the goals delegated to him. As long as he generated the level of profit for the larger organization that was thought to be reasonable by the central office, he had a great deal of freedom to run his division as he thought best. Most of the influence of the central office was purposely limited to budget control, setting the salary of the division chief, and firing him if performance was unsatisfactory (Chandler 1990, 449).

Each of the functional departments within a division was organized around and performed a set of operational tasks for only that division's product line. This focus reduced the administrative burdens of department offices, and allowed them to refine their organization to capture economies of scale and produce high quality, marketable products within that product line.

In essence, each division of the larger multidivisional organization was a replica of the early "centralized, functionally departmentalized" organizations (Chandler 1990, 449). In theory, this allowed corporations to diversify and expand indefinitely without generating serious management problems. Each time they added another division, they were essentially adding another corporate manufacturer with its intact management structure while still completely incorporating it into the management hierarchy of the larger corporation. This gave the central offices of multidivisional corporations an enormous degree of strategic flexibility to directly control even large parts of their relevant sociotechnical systems.

In the central office, “the top managers became general executives without day-to-day operating responsibilities” (Chandler 1990, 449). This freed up more time and resources for central offices to focus on the long-term strategic outlook of the corporation as a whole. It helped to isolate the central office from the parochial interests of each division and easier to be responsible for the organizational as a whole. Because top executives were usually compensated based on the performance of the firm as a whole, they knew that their careers depended on the decisions they made to help the organization as a whole. In other words, the multidivisional form gave central offices the resources and the incentive to centrally plan, evaluate, implement, and oversee system building, even if it means liquidating one part of the organization or destroying parts of the existing external system so long as it increased the overall rate of return on the company’s capital investments.

The central offices of multidivisional corporate organizations became superbly suited for the task of complex system building, particularly for introducing systematic innovations into tightly coupled systems. As noted by Pavitt,

> the strategic exploitation of technology at the corporate level requires a strong technological and managerial input at the centre, in order to exploit synergies and to redesign organizational missions and competencies [and reallocate organizational resources] in the light of emerging opportunities (Pavitt 1992, 31).

These central offices acted as a hub of information about the general activities in each part of their organization and about external parts of the system. It then coordinated the parts of the system during system building endeavors either through its internal management hierarchy or by deploying its organization’s capacities to control the external system.

Top management was assisted by teams of specialists in accounting, personnel, public relations, and engineering to help conceive new plans and evaluate strategic options. These specialists engaged in a set of routines to maintain a "constant flow of information" and advice about the activities in each division. Financial data was, of course, the most important information. Because the central office intentionally stayed out of touch with day-to-day operations, it needed a broad set of financial indicators for the general state of each division. They invented specifically for this use of the ratio of rates-of-return-on-investment to turn-over-in-capital and the ratio of rates-of-return-on-investment to volume-of-sales (Chandler 1962; 1990).

One of the most important system-building activities that a central office could undertake was to build new organizational capabilities for system building including central R&D laboratories, marketing capabilities, attorneys, lobbyists, public relationship experts, and sometimes an office to make philanthropic donations to co-opt and exert influence over external organizations—each with their own set of routines ready to be engaged and deployed against the external system arrangement. Firms often established a strategic development office to tie all these activities into a single corporate plan and that played a key role whenever the organization planned R&D activities, new product lines, mergers, acquisitions, and selling off parts of their organization.

While divisions were often allowed to have their own R&D and marketing capabilities for improving existing production processes and products, central offices felt a strong need to have their own central R&D and marketing capabilities that were separate from the parochial interests of each division. These were useful for two reasons: *First*, central R&D labs were more inclined to conduct research of a more fundamental, long-term nature to the benefit the organization as a whole. Second, it was easier for these labs to undertake an R&D project that one or more divisions might perceive as a threat to its jobs, technology, or status. Central labs were crucial to the coordination of those R&D projects that needed the technological and scientific expertise of more than one division, which was applicable to many of the most important new technologies. An example of both is DuPont's long-term basic research that yielded the radically new synthetic polymers that needed the cooperation of two different divisions (Reich 1985; Pavitt 1992; Chandler 1990; Hounshell and Smith 1985; Fligstein 1990).

Central offices wielded the ultimate means of control, which of course was financial control that was used to allocate or withhold resources to divisions. These decisions were based on projected returns on investment. By the early post WWII era, DuPont was using market analysis and sales forecast techniques that allowed them to make predictions within 5% of the actual value (Fortune cited in Fligstein 1990). The central office would often reallocate profits from the divisions with a projection of low returns on investment to the divisions with a projection of high returns on investment. Of course, divisions were not just competing with each other for investment capital. They were also competing against any potential new product line that came out of the central R&D lab, or, for that matter, any related product line that was manufactured by other corporate organizations that could be acquired. Thus, divisions had substantial motivation to make their product lines as profitable as possible, and to use their divisional R&D labs and marketing departments to constantly improve products and increase market penetration and to add new products to replace those with declining sales (Fligstein 1990).

More needs to be said about financing system building through the central office. Typically, access to investment capital has been a limiting factor to system building. Although most corporations with a reasonable credit rating could borrow money, the lenders would usually place constraints upon how it could be used (Mintz and Schwartz 1986). Traditional lending institutions have been reluctant to finance R&D projects for unproven technologies and nascent sociotechnical systems. It was too risky. Likewise, corporate system builders were reluctant to put their own firm up for collateral to finance these high-risk endeavors. The failure rate for R&D projects was about 9 out of 10 according to Pavitt (1992) and was too high to risk an already profitable part of their organization.

This meant that corporate organizations had to self-finance most of their most creative system-building activities, which usually meant the use of retained earnings (Chandler 1980, 34). When retained earnings were available, it was by far the best way to finance system building because it allowed firms the maximum amount of flexibility as to what system-building endeavor in which to engage. Of the corporate organizations that engaged in the most successful system building in the early 20th century, such as DuPont, GE, AT&T, Ford, and GM, all had access to large amounts of retained profits.[30] Often this was from some type of monopoly or oligopoly control of their market. For DuPont it was its monopoly control over wartime sales of explosives and powder. AT&T was able to finance its early system building from the monopoly it had held based on the patents of Alexander Graham Bell (Reich 1988; Hounshell and Smith 1988). More over retained earnings were a source of investment capital that could be allocated flexibly and quickly to any system-building activity that a central office thought was important. They did not have to specify or justify to any external organization or individual how that money would be invested, which usually needed to be done with external financing from venture capitalists and banks. Large amounts of retained earnings allow corporate organizations to take risks. Likewise, it increased their ability to take advantage of new technology and market opportunities and to adapt to external threats faster than their capital starved competition.

Less profitable firms had to resort to other ways to finance system building, which included cannibalizing one of their least-profitable divisions by diverting its profit stream to a division with higher projected profits. All divisions had to have a continuous stream of investment capital to replace aging equipment and to engage in continual product improvement. Thus, this had the effect of starving the former for the sake of the latter. Firms would also sell off divisions either intact or piece-by-piece to finance growth and system building. These techniques to raise investment capital were conducted not only by companies desperate for investment capital, but also by highly profitable companies.

A lucrative technique was developed in the 1950s that allowed small capital starved firms to buy larger firms. This was the leveraged buyout. Using purchased firms as collateral, firms could buy other firms. Because very little cash was needed for such investments, small firms have been able to swallow up much larger firms using this technique, although at a fair amount of risk (Fligstein 1990). Also, particularly in the latter half of the 20th century, sophisticated capital markets evolved including venture

[30] Obtaining investment capital from out side of corporate organization is usually more expensive because interest rates must be paid on it. Selling stock and other methods of external financing also have a set of costs and tradeoffs.

capital markets and stock markets, which have increased corporate organizations' access to investment capital that can be flexibly used for system building. Nevertheless, investment capital is still often a limiting factor to system building, and retained earnings are still very important.

Protecting and Enhancing Growth: Lobbying, Litigation, Public Relations, and Donations

Of course, corporate organizations often have offices of government relations, teams of litigators, public relations specialists, and grant giving programs that can play important roles in their system-building efforts. In particular, they can be useful to exert a degree of control over the external parts of a firm's relevant sociotechnical system. If firms do not have these specific organizational capabilities, the central office will often contract with external organizations to deploy their organizations on behalf of these firms. As noted by Chandler (1990), there is usually a vice president in charge of a public relations/government affairs office to coordinate these capacities whether they are located internally or contracted externally. There appears to be little research on the organizational aspects of these activities by corporations. The view in this analysis is that routines for litigation, lobbying, public relations work, and corporate donating programs are important, but they are probably best considered as auxiliary structures for system building.

Conclusion and Additional Theorizing

By the early 1930s, a hand-full of corporations developed into one of the most sophisticated organizational forms yet devised for controlling the pace and direction of sociotechnical change. This organizational form was, of course, the strategic, multidivisional, vertically integrated, research-orientated, corporate organization (SMVRCO). The uniqueness of this organizational form was that in addition to capacities for maintaining the existing system, it also had specific organizational structures that it used as capacities for system building, including a strategically focused central office, centrally controlled R&D, and marketing capabilities. Also, when it deemed appropriate, the central office had the ability to one degree or another to co-opt the organizational capacities for maintaining the system for building new systems arrangements even when it threatened existing production technology. By the

1960s, this organizational form or a modified version of it was adopted by a substantial majority of technologically orientated corporate organizations.

SMVRCOs have demonstrated the ability to be highly adaptive and innovative, particularly when their management wants them to be and even sometimes when it makes their own production technology obsolete. In the name of adapting and innovating, SMVRCOs and other strategically minded corporate organizations have shown their willingness to destroy production technology by replacing human workers with automation. They have cannibalized entire divisions that are underperforming—selling them off piece by piece—to generate investment capital to pay for new divisions, departments, and other operating units with predicted higher returns on investment. Also, and most relevant to this study, SMVRCOs have repeatedly shown the ability to generate new inventions and sometimes even radical ones and turn these into marketable products that replace their existing products and product lines often with considerable speed. One such example was DuPont's R&D program to bring synthetic polymers to the marketplace as a substitute for both natural polymers and its own production technology for semi-synthetic fibers. Through controlling technological change with its R&D capabilities, DuPont's central office predicted that it could capture a larger market share with synthetic polymers than it could with its semi-synthetic fibers.

Despite conventional wisdom that large corporations are entrenched in the status quo and cannot be innovative, this chapter suggests that in fact these organizations can, when they decide that it is in their interests to do so and when they have the organizational capacities. Innovation and system building is actually routine business for the central offices and other organizational units of SMVRCOs, and often involves highly rationalized decisions to maximize profit and organizational growth and the significant ability to restructure the major parts of the sociotechnical system to achieve those goals.

Most firms of other organizational types—such as small businesses, holding companies, and f-form organizations—do not appear to have the same degree of adaptability and innovativeness. Their organizational structures are typically limited to maintain existing system arrangements. Henry Ford is a well known, but certainly not usual, example of an original inventor/entrepreneur who managed a classical, f-form corporation who resisted new innovations largely because his own identity was invested in the systems arrangements that he had created. Likewise, although small firms are often highly inventive, very few of them have the organizational capacities to be innovative enough to turn those inventions into a product for a large market. Of the few that do succeed, it appears to be through growing into a large corporate organization with a full set of capacities for system building or teaming up with a corporate organization that already has such a set of capacities (see Pisano, Shan, and Teece 1988 for similar comments).

These organizational capacities of SMVRCOs that give them their prowess at system building are important enough to summarize. Also, many of the basic structures and routines that embody these organizational capacities or a variation of these appear to be adaptable to other organizations. For this reason, it will be particularly useful to identify and describe these structures and routines to aid the development of a practical, hands-on theory of system building.

One of the most important of these is the strategically focused central office, of which a few different structures are relevant. First, it appears that the central office must be somewhat insulated from the day-to-day activities of the firm so it both has the time to focus on strategic matters and also its interests are not too heavily vested in the status quo. Being from a generalist professional background instead of one of the functional activities of the organization also seems to be important. Second, the central office needs to have specific organizational routines for strategic evaluation, planning, and oversight. It is, of course, possible to contract out some of these activities such as evaluating the benefits of a merger, but theoretically it would be necessary to have at least some of these capacities in-house in at least a rudimentary form in order to specify the work that needs to be done, coordinate with outsourced capacities, and incorporate the recommendations into the organization.

Centrally controlled routines for invention and innovation are crucial to be able to successfully create new parts for a constantly evolving system and then integrate those new parts into the system. Using centrally controlled R&D labs to generate new inventions and then develop these inventions into new, marketable products is the most common example of this. However, although this chapter has not discussed the matter, inventions can be social as well as or technical. Social inventions can include new organizational, institutional, or cultural arrangements. Also, technical inventions can include new production processes and equipment as well as new products that were primarily exemplified in this chapter. At a high level of abstract, the process is theoretically very similar for integrating new parts into a system, regardless of the type of part. It involves generating a new invention, evaluating the fit of it with the system, adjusting that fit where necessary and then engaging in additional iterations of each of these steps as needed.

New product R&D units have one of the most highly rationalized and developed sets of routines for invention and innovation. It seems that DuPont's use of its new product R&D abilities to successfully develop nylon can be used as a very good example of an ideal process for invention and innovation regardless of whether an invention is social or technical. The process is to 1) very specifically choose what invention should be fitted into what specific set of structures in the larger system, 2) make an investment of time and money into studying both the basic invention and the relevant systems arrangements before beginning lab work, 3) make an additional investment of time and money into a well thought out plan for system building, 4) begin an evaluation of the fit between the invention and the larger system at a reduced scale and scope (i.e., initial lab work or a small-scale pilot study), 5) adjust the invention and/or the larger system to improve the fit, 6) pursue additional iterations of step 3 and 4, (7) when the fit is sufficiently improved, increase the scale and scope (e.g., to a middle size pilot study) and continue iterations of evaluating the fit and adjusting the fit between invention and system, and finally (8) increase the study to full scale and continue with iterations of evaluating and adjusting the fit.

The above is the process of invention and innovation in the context of system building. However, actual success at this process will depend on whether an organization has specific organizational routines for 1) strategically planning the process including the choice of which invention upon which to focus, the place within the larger system in which to integrate it, and determining criteria for increasing the scale and scope of the innovative process, 2) gathering information about the fit between the invention and the system using lab work and management hierarchies to collect information , 3) adjusting that fit by re-engineering the invention and using management hierarchies and marketing, lobbying, and/or purchasing units to reshape systems arrangements where needed, and 4) flexibly funding all of these activities.

Co-opting Structures for System Building

As theorized, many of the above routines for access and adjusting the fit of inventions are capacities for maintaining the existing system that have been co-opted for system building. These include the management hierarchy and sources of funding. I say co-opted because they are primarily used for managing and funding the existing system arrangement, and the people that staff those routines have a vested interest in maintaining existing system arrangements even though they are being ordered to participate in the possible demise of the status quo.

Management hierarchy: A well-developed management hierarchy that is vertically and horizontally integrated into many parts of the system can be a very important source of information, control, and coordination if co-opted for system building. Most SMVRCOs have these kinds of management hierarchies to one degree or another. They are usually integrated into downstream production and upstream distribution and sales. Also, they are often integrated into various auxiliary capabilities such as purchasing, public relations, lobbying, and legal work that can be used to influence systems arrangements external to the organization. Large SMVRCOs such as IBM, Microsoft, and DuPont are successful system builders in part because they have at least some direct or indirect control over many different parts of their respective industries and relevant sociotechnical systems. When trying to introduce systematic innovations, having this much control over so many parts of the system is very valuable.

Sources of funding: The functional units of a corporate organization that engage in production, distribution, and sales are capacities to maintain system arrangements that can be sources of very significant financial resources to flexibly fund system building. Although many division chiefs would likely prefer to have their profits stay within their own division, central offices have the legal authority to divert financial resources from one division to another, and they often do as a matter of routine business.

Part III

Chapter 6: Residential Housing and Sociotechnical Change

The residential housing system has been characterized by rather slow, autonomous technological change. In the previous chapters, we have seen how corporations from different industries increased the size, complexity, and strength of their capacities for system building through vertical and horizontal integration, managerial and market control over parts of production, distribution, and selling, strategic separation from operational management, and R&D and marketing departments. An outgrowth of R&D and marketing was the whole-design approach to product development where the fit of a new product with the rest of the sociotechnical system was given heavy consideration. These capacities and strategies allowed for unprecedented control and coordination of the direction and pace of technological change.

However, residential construction has not been one of these industries. This chapter primarily focuses on the single family, detached, new residential construction. Although the most attention is given to site-built homes, other building systems are discussed, and mobile/manufactured homes are compared and contrasted with modular construction. Historically, homebuilders have tended to be small, local firms in a very fragmented, decentralized industry. Very frequently, the construction and sale of homes is conducted by dozens of different kinds of small, highly specialized firms such as realtors, bankers, appraisers, contractors, and subcontractors when in most other industries these specialized tasks have been integrated into single firms. This lack of integration and sophisticated organizational structures has made it very difficult for construction firms to facilitate the introduction of systematic innovation. Firms are usually too small to have the capacities for engaging in either whole-product design or to exert any substantial influence on sociotechnical change.

There are no “large builders” of homes by standards of the larger economy. A builder of single-family homes would be called “large” by its peers if it constructed about 200 units and did $3 million in construction work per year with a staff of 32. In 2000, the largest US builder, Pulte, sold 36,200 housing units (Heavens 2002). However, General Motors produced that many cars[31] in a day and a half!

[31] General Motors produced 8,494,000 autos and light trucks in 2000 (General Motors 2003).

Technological change has proceeded very slowly in this industry. A large majority of the basic technical components of homes that are associated with mainstream construction have been available for decades and some for more than a century. For example, central heating and cooling and fiberglass insulation have been used for decades. Electrification and indoor plumbing have been around for over 100 years (Doan 1997). Stick built construction had been in use since the very early 1800s via the French influence on the Midwest and later popularized in Chicago in the 1830s (Cavanagh 1999). Gabled roofs are even older. Even some of the basic ideas that are associated with the cutting edge in the residential housing system have been around for just as long or even longer, although they were less widely used. For example, and steel construction and straw bale technology have both been around for over a century (Doan 1997). Likewise, active solar energy and fluorescent lighting have been available for decades, and passive solar technology has been around for even longer.

However, some have suggested that technological change in the industry is not as slow as it appears (Slaughter 1991; 1998). Also, there have been a fairly large number of new inventions in the industry, but mostly through rather autonomous innovation from the periphery of the industry, not systematic innovation from its core. I do agree that the issue is more complicated. Lutzenhiser and Janda (1999; 2001) have noted stylistic technological changes that have occurred such as the trend away from traditional ranch style floor layout to a more open-plan, multi-story, larger homes with multiple bathrooms and higher ceilings. These have included new adhesives, fasteners, covers, coatings, and new materials such as orientated strand board as a replacement for plywood. The industry has also seen new heating and cooling equipment, such as the heat pump.

Moreover, as will be discussed below, most of these autonomous innovations have been from inventions that came from the periphery of the residential housing system—from firms that manufacture construction inputs as one of their many product lines, such as Dupont and Dow Corning. Another notable feature of all these technical changes is the characteristic of being autonomous innovations. These have been inventions that were designed to be plugged into an existing set of building plans with little or no change to how the rest of the dwelling was built or would function. Slaughter (1991) listed most of the major innovations in residential construction in the years from 1945 to 1990, and the Building Research Board (1992) did similar for HVAC from 1965 to 1990. After examining their work, most innovations in their lists appear to be this type of plug-and-use technology. [32]

The overall conceptualization that has been used to design and build a large majority of homes—how to provide structural support, how to electrify them, and how to heat and cool them—has remained essentially unchanged for decades (also see O'Brien and Martin 2004). This makes the residential housing system rather unique compared to the design and production of other technically and socially sophisticated consumer products. New computers are essentially obsolete in three years or less. Likewise, an automobile mechanic trained to work on cars in the 1970s is lost trying to work on cars manufactured today. In contrast, many of the homes built 80 years ago are still widely used and considered valuable real estate, a highly skilled craftsmen trained in the 1940s would be very able to work in the current residential construction industry. Actually, such craftsmen would be over-qualified for the assembling of prefabricated components that dominates much of the new construction in the industry today.

Despite the fact that residential homes are highly systematic technological products, very few builders have fully adopted whole-house design and building. The whole-house approach to building takes the view of a "house as an integrated system, rather than a collection of products and parts, to deliver a better home" (McNulty 2003). This holistic approach to the design of residential dwellings tries to optimize the performance of each subsystem in the home and to increase its fit with the broader sociotechnical system. Many of the most innovative technologies—such as straw bale construction, steel frame, passive solar heating, and air tight construction—that have the greatest potential to improve quality and reduce price, to save energy and reduce the impact of construction on the environment—are systematic innovations. However, these require a fundamental rethinking of how houses are built, financed, appraised, and sold.

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[32] The phrase plug-and-use technology is as an analogy to "plug-and-play" computer hardware. Plug-and-play computer hardware has the advantage of not needing reconfiguration of the relationship among that piece of hardware other parts of the computer.

A Unique Industry

The slow conservative technological change of the housing industry is certainly not because there are a lack of technical inventions. Hundreds of devices, materials, and techniques have been available, for example, to make residential housing more energy efficient. However, even among those that have been technically and economically feasible, most have had little market success (DOE/BTS 1999).

The reasons appear to be the unique nature of residential dwellings as sociotechnical artifacts and the historical organization of the industry, which are closely related. The difficulty of transporting houses from a central production facility has been deterrence to the use of off-site mass production techniques. This has blocked access to mass markets that, in turn, are necessary to justify the expense of large-scale production facilities, sophisticated organizational structures, and capacities for system building. Firms that make mobile/manufactured homes are a notable exception, which will be discussed.

It was argued that complex organizations with well-developed capacities for system building are usually needed to successfully facilitate the introduction of systematic innovations. All new technologies are systematic innovations to one degree or another, but residential dwellings appear to be much more so than many others. Houses are constructed of a more complex set of technical parts and subsystems than most other end-product technologies, and they have a more complex set of relationships with the larger sociotechnical system. This contributes to their uniqueness, and it greatly complicates the introduction of many new innovations in the residential housing system.

This lack of capacities for system building within the housing system appears to be the direct reason for the lack of systematic technological change. It typically requires at least moderately large, complex organizational structures to engage in intensive whole-house design and building. For every part of a house that is to be designed, built, and integrated with the rest of the house it is necessary for the organization to have the organizational capacities in-house or coordinated through network relationships to fund, get information, plan, control, and coordinate that part. It is not necessary, nor is it realistic, for every aspect of the needed organizational capacities to be within a builder's firm, but it still requires significant capacities to fund and coordinate the activities that are out sourced.

All said, residential housing is a rather unique industry. The sociotechnical characteristics of residential homes as an artifact and the historical organization of the processes of building and selling residential homes are very different from other industries. In the rest of this section, I will take a closer look at these unique characteristics to better understand how they have made it problematic for the industry to develop organizational capacities for system building.

Residential Dwellings as Complex, Technical, and Social Artifacts

A residential dwelling is a complex technical system with many subsystems including structural elements, exterior sheathing, insulation, electrical wiring, plumbing, lighting, and interior coverings. Each of these subsystems are made up of hundreds of materials, parts, components, and devices that can interact with each other and other subsystems to produce attributes that characterize a house as a whole. These attributes include interior layout and design, durability, ambient air quality, and thermodynamic properties. In other words, the whole is greater than the sum of the parts (Slaughter 1991).

These parts of a house contribute to its overall performance through many non-linear, synergistic, and antagonistic relationships. Consider how the parts of a house and its location can contribute to its thermodynamic characteristics. This is essentially an issue of how much thermal load the external environment places on a residential dwelling, how much protection the dwelling provides to its internal space, and the efficiency of the HVAC system to condition the internal air. The external load is dependent on a handful of location-dependent factors that include the topography, vegetation, other buildings upon a site, and the orientation of a dwelling to the sun and prevailing winds. Important characteristics of the dwelling include the R-factor of exterior walls; completeness of the vapor barrier; albedo factor of the exterior wall and roof; the number, type, and locations of doors and windows; the amount of unconditioned space next to exterior walls; a roof with enough overhang to shade the rest of a house in the summer but allow the sun to hit it in the winter; and the amount of mass available to absorb the solar radiation that makes its way through windows. The efficiency of the heating and cooling system is influenced by the efficiency of the heating and cooling units, how well matched the capacities of these units are with the heating and cooling load of the home, the location of the heating and cooling equipment in a home, how airtight the ductwork is and how straight its path is from the heating and cooling units to the conditioned space, and likewise for the return air ductwork and fans (Cooper 1998).

Of course, the technical parts of a residential dwelling are interconnected with the social parts of the larger sociotechnical system. Many of the above physical characteristics of a residential dwelling are interrelated with a set of cultural values, consumer preferences, and perceived needs that structure market demand. These include the exterior and interior design, number and size of bedrooms and bathrooms, location, amenities, comfort, energy efficiency and affordability.

These sociotechnical characteristics make residential dwellings one of the most personal and certainly the most expensive purchases that an average person will ever make. *Because of this, most homebuyers are willing to pay a significant amount of additional money for assistance from the third parties who both help make their purchases of homes financially possible and increase their chances that they will obtain the home they want without any liabilities and technical problems.* Typically, these third parties are bankers, real-estate professionals, appraisers, code officials, title companies, insurance companies, home inspectors, and other consultants that are embedded in an extensive set of contracts, codes, regulations, and laws about how industry actors interact with each other and with home buyers and sellers in regard to health, safety, environment, energy efficiency, economic equity, and many other issues (Lutzenhiser 1994). These third parties and the institutional framework in which they operate are also part of this larger sociotechnical system. Also, the firms that manufacture the materials, supplies, components, and tools that are used to build residential housing are part of this larger sociotechnical system. Of course, builders and subcontractors are as well. This chapter will spend a great deal of time on the organizational capacities of builders and subcontractors to engage in system building, and how the lack of these capacities results in very conservative technological change.

Airtight construction is an example of a rather systematic innovation. Airtight construction is actually a set of many different construction technologies that must include materials (e.g., house wrap), components (e.g., airtight windows and doors), and building techniques (e.g., framing techniques) that must be integrated together. However, before airtight construction techniques can be fully adopted, changes are needed in the rest of the system. The *first* place is the training of architects, engineers, draftsmen, and construction laborers about the interactions among the various technologies that make up airtight construction techniques and with the rest of the home. The upper reaches of energy efficiency from airtight construction are only obtainable through attention to details in both the design of a dwelling and during the construction process, which requires training beyond what many designers and most semi-skilled and unskilled laborers would typically receive. However, if a dwelling is to be built as airtight as technically possible, changes are needed in other subsystems of a residential dwelling. This is the *second* place where changes are needed. Unless heat exchange systems and equipment for the proper ventilation of combustion gases are installed, airtight dwellings will usually have a number of unwanted side effects, such as unwanted moisture that leads to mold and decay and the retention of waste gases. Both mold and waste gases commonly cause health problems, which appear to be a market barrier to airtight construction at least in some markets[33] (also, see Slaughter 1991).

The *third* place where additional changes are needed if the maximum amount of efficiency is to be obtained from airtight construction is in the market demand for energy efficiency. Except for those who purchase high-end housing, homebuyers typically do not want to finance or pay for the extra up-front costs of airtight construction. They are either more concerned about higher monthly mortgage payments or want to use all their buying power to purchase as large of a house with as many amenities as possible.[34] A *fourth* place for additional system building is in the financing of residential housing. In particular, mortgage products are needed that both extend the borrowing limits for the extra expense of energy efficiency so homebuyers do not need to forgo other housing features and that acknowledge that the cost of energy efficiency technology will be offset by reduced energy bills (Farhar and Eckert 1993). Of

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[33] These problems were observed by Greg Nahn of Wisconsin Energy Star Homes (personal communication in the summer of 2003) and also encountered by builders from Lincoln, Nebraska (data from interviews during field studies).

[34] Evidence of this was gathered through interviews by the author of energy efficiency professionals and from

course, there are other places in the system were change would help the market success of a systematic innovation such as airtight construction, but these are probably the main ones.

In contrast to many other industries, firms that have populated the residential housing system have had few organizational capacities for system building. The firms are too small, fragmented, and with little vertical and horizontal integration to adjust the fit between technical inventions and the rest of the system. The industry has not been quick to adopt the centralized, mass production techniques that have stimulated the development of large, complex organizations and capacities for systems building that have developed in other industries.

There have been technical/physical and social characteristics of residential dwellings that appear to hinder the use of mass production techniques at centralized facilities, and that have thus prevented the development of more sophisticated organizational forms.

Characteristics of Housing that Make Mass Production Difficult

Homes have commonly been constructed from materials not ideally suited for the mechanized fabrication and assembly that characterizes centralized, mass production facilities. In the 19th and early 20th centuries, residential dwellings have been made almost entirely from wood including the frames, roofs, singles, siding, paneling, flooring, and interior trim and finishing.[35] However, as needed in mass production techniques, wood has been difficult to fabricate within high tolerances, has limited versatility of shape, and is awkward in many machine assembly processes (McCutcheon 1992).

Nevertheless, wood and wood products are still heavily used by contemporary builders, even though plastics, metals, autoclaved aerated concrete, and other non-wood materials appear to be a strong, durable, cost-effective alternatives to wood (Smith 1996; National Home Building Research Center 2001a) and

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documents that were analyzed.

[35] In this time period, many other commodities were made of wood such as tools, toys, boxes, fences, furniture, boats, and carriages. Automobiles were also extensively made of wood, which included the frames, chassis, and trim and smaller parts, until the 1930s when the use of the natural material quickly declined (Sutherland 1972; Clarke 1999). During the 30s, car companies began to quickly switch to steel frames and chassis. By the 1950s, very little wood was used in the auto industry (Sutherland 1972; Clarke 1999) or the broader economy. Plastics and metal alloys had started to dominate.

more amendable to mass production. Traditions among builders and the cultural expectations of homebuyers are likely reasons why these materials have not been adopted on a wider scale.

On the demand side of the relevant sociotechnical system, there are additional reasons why mass-produced homes have not had more market success. Traditions and local physical conditions appear to be important. Homebuyers have come to expect a very wide range of choices among architectural designs, number rooms, and amenities that fit their personal tastes and needs (Lutzenhiser 1992). Also, for a residential dwelling to be durable, efficient, and comfortable, there are individual requirements for each house that are dictated by climate and geophysical characteristics of its final location. Local building regulations have also been a factor (see McCutcheon 1992, for examples). These are issues that will confound standardization and make mass production difficult.

Also, the large bulk and mass of residential housing units made these difficult to transport from a central manufacturing facility to the site of their permanent foundation (McCutcheon 1992). Historically, the laws of some jurisdictions and the type of roads, height of overpasses, and the amount of traffic have limited the size of these dwellings that were transportable. However, even after the adoption of suitable laws and a more developed transportation infrastructure, the transport of pre-assembled residential dwellings has remained a slow, cumbersome, expensive process. These problems still significantly offset many benefits of using centralized, mass production facilities to make residential housing units.

Cyclic Nature of the Housing Market and Problems for Mass Production and R&D

The cyclic nature of the residential housing industry appears to have had major implications for the type of construction technology and the building processes that have been used. Specifically, given the widely fluctuating and unpredictable markets for residential homes, it appears that building firms have had a hard time justifying long-term investments into capital-intensive, centralized, mass production facilities and into R&D projects to control technological change. Also, because of the cyclic demand for residential housing, there is a high turnover rate for labor, and, thus, builders have little incentive to invest in the training of labor. As a result, builders tended to favor on-site construction processes that use subcontractors, unskilled labor, and minimal capital (Manski 1973; Slaughter 1991; Office of Technology Assessment 1986c). The residential construction industry usually suffers a shortage of skilled labor (Piper and Liska 2000).

However, the use of temporary, minimally trained laborers makes it difficult for builders to establish complex work routines that it can easily control and coordinate for introducing systematic innovations. Likewise, subcontractors who usually do most of the actual construction work often do not have laborers with a set of skills and routines to consistently build homes to code[36] or use new innovations job after job.

It would be risky for builders to make long-term investments into centralized, mass-production facilities and into R&D facilities to control technological change because the entire residential construction industry is very sensitive to fluctuations in the larger economy. Homebuyers typically need to seek external financing, and demand is thus sensitive to interest rates. In addition, most builders use external financing for construction (Lutzenhiser and Janda 1999; Berman and Pfleeger 1997). The widely fluctuating demand for housing makes it very difficult for builders to estimate whether capital intensive investments will pay a reasonable return.

This is a reason why it is very attractive to use the tried and proven, unskilled, labor-intensive, building process. As commented by Twiss and others, payments to the bank are sunk costs that must be paid, whereas expenditures on labor require less of a commitment. Workers can be more easily laid off when demand for homes drops and then acquired again on short-term contracts when demand increases. However, researchers cannot so easily be laid off and later rehired as easily as other employees because researchers have firm specific, tacit knowledge that is expensive to learn and can be difficult to find on the labor market (Twiss 1986; Himmelberg and Petersen 1994). Furthermore, because most builders are small firms, they do not have the financial reserves to survive a drop in demand. Thus, it is even harder to

[36] In a personal communication with Phelix Lee, Director of Building & Zoning Department, City of Fort Collins, on June 18, 2000, Mr. Lee commented that from his perspective when builders and contractors do not build to code, it

justify the risk of expensive, long-term investments into production facilities and R&D projects (Building Research Board 1992; Manski 1973).

This labor-intensive description of home building is supported by evidence from the Census Bureau. The construction process in the residential building industry is much less capital intensive than any other major industry that makes products to be sold to directly to consumers. In 1997, the amount of capital assets that were used by builders in the residential housing industry to construct single-family homes was five times less than the average in the manufacturing sector on a per dollar basis of value added output. For subcontractors such as plumbing, heating, ventilation, and air conditioning, electrical work, and roofing and siding, the use of capital per dollar of product sold was four times less than the average firm in the manufacturing sector.[37]

The cyclic economy also encourages the use of unskilled, often temporary labor and the practice of subcontracting. To the frustration of contractors, laborers work on a project or two and then leave when work becomes unsteady (Building Research Board 1986). When demand increases, these laborers must be replaced and often retrained. The reliance on subcontracting seems to help avoid the hassles and risks of hiring and training laborers. However, it makes it difficult for a firm to develop complex work routines that can be easily controlled and coordinated, which is extremely important when trying to incorporate new technology into a building process when that technology requires a unique or specialized skill set.

The construction industry has always had problems with shortages of labor and particularly skilled labor and management during boom periods in the economy. Koomey (cited in Lutzenhiser & Janda 1990) estimated that less than one percent of the architects and engineers have the necessary skills to design state of the art energy efficiency commercial buildings. If Gunderson (2001) is correct that

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usually not dishonesty but not knowing how to do the job correctly.

[37] These numbers were calculated using data from various industry series of 1997 Economic Census by the U.S. Census Bureau (1999a, 1999c, 1999c, and 1999d). For the average manufacturing firm, the ratio of capital assets to value added was 0.85, for builders that constructed single-family residential dwellings it was 0.17, for plumbing and HVAC contractors it was 0.21, for electrical contractors it was 0.20, for roofing, siding and sheet metal contractors it was 0.24. The term “builders” is mean to include general contractors, operative builders, and construction management services. In addition, it should be noted that the data on these subcontractors are about construction if single-family homes, as well as multifamily homes and commercial industrial, government buildings, et cetera.

commercial builders tend to employ some of the most qualified labors and managers, then residential builders probably employ even fewer. Gunderson also argues that residential builders tend to have less management and personnel skills than other major industries. Likewise, according to the Center to Protect Workers Rights (1997), the construction worker has less formal training than any major sector of the economy. In a 1997 national survey, approximately 92% of construction firms indicated that they had a shortage of skilled labor, and over 85% said their current workforce is not as skilled as it needed to be (Shelar 1998).[38]

Again, these are reasons why the firms in the residential construction industry have not historically invested in vertically integrated mass production facilities and R&D abilities that have characterized other industries. As Chapter 4 suggested, it has been these centralized production facilities and R&D abilities that have been the sources of dynamic sociotechnical change in their respective industries. In most other industries, the emergence of a speedy, dependable transportation system allowed access mass markets, and this in turn made it lucrative to develop mass production facilities, mass distribution networks, and mass marketing capabilities, and to integrate into downstream production. Many of these manufacturing corporations amassed a great deal of wealth that they were able to invest in expensive, risky, long-term endeavors to radically transform their relevant sociotechnical systems. Likewise, many of them assembled a sophisticated set of organizational capacities for system building. This has not been so with most residential construction firms.

Historical Efforts to Industrialize Residential Construction

Although there has been some industrialization and system building in the housing industry, change in the residential housing system has followed a different path. Despite the obstacles to mass production techniques, the promoters of "industrial building" systems have clawed away at the market to gain a small

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Nevertheless, single-family residential homes have the largest share of these markets.

[38] Gunderson (2001) and Lutzenhiser and Janda (1999) commented about the difficulties of acquiring human resources in the construction industry. Many other industries that are strongly influenced by cyclic activity have tended to shy away from long-term capital investments, for example the petroleum industry as described by (ICF 1976).

but significant and seemingly stable share of new residential home sales. Industrial building is the idea that "housing should be produced as far as possible in a factory by methods which are in principle similar to those used in assembly line mass production" (McCutcheon 1992, 353). Historically, industrial building has included *modular housing*, which is almost entirely built in factories; *panelized systems*, which are sets of floors, walls, roofs, etc. that are fabricated in a factory and shipped to location for final assembly; and *precut* lumber, such as log houses. However, mobile/manufactured homes have not been part of this collective effort. Historically, the firms that made mobile/manufactured homes were very different from those that made industrial housing and their development and success has taken a different path. For that reason, mobile/manufactured homes will be discussed separately.

Here I will explore these and other historical efforts in the residential housing system to industrialize the construction process and engaged in related system-building activities.

Pre-World War II Forms of Organization and Rudimentary System Building

Residential dwellings are hardly new. For tens of thousands of years, humans used a wide variety of techniques and materials to construct their homes, but there is no need to go back that far. The beginning of the industrial revolution in the 1800s of the United States is a reasonable starting place. The two most common organizational forms for new residential construction were the small business model with small, local craftsmen as proprietors and also homeowners who self-constructed their own dwellings. Until around WWII, the vast majority of homes were built through one of these two ways to organize the construction process (Doan 1997, 12; Harris 1991). Afterward the second WW, general contractors and the use of prefabricated parts became increasingly common.

Little is definitely known about the residential housing industry before WWII. However, researchers have suggested that self-built housing was responsible for a very substantial share of new home construction (Simon 1978; Zunz 1982). Harris (1991) argues that one of the main differences between self-built and craftsman built housing was quality. Because many owner/builders could not afford nor did they have access to carpenters and store-bought materials, self-built homes were usually constructed of lower quality methods and materials. Self-builders often used of whatever materials and techniques that were available.[39] These self-built homes tended to be located in the suburbs and rural areas outside city limits where there was no code enforcement and land was cheap. As codes became more common in the 30s and 40s and as the rest of the economy industrialized, there was a decline in self-built construction as the residential construction industry was slowly industrializing.

Housing construction by craftsmen is of greater interest to this study than self-built because it was a more recent and more direct organizational ancestor of modern builders. These traditional craftsmen were small, local builders who fabricated essentially all building materials out of local raw resources and assembled every part of the house on site. They made their own rafters and wall frames, and also their own doors, windows, and shingles (Vill 1986; also see Office of Technology Assessment 1986c). By being generalists, these craftsmen used a highly integrated building process and had complete control over every stage. However, it was a very different type of integration from that of modern corporate organizations that achieve integration through placing many different kinds of specialists into a management hierarchy. Subsequently, the organizational forms used by traditional craftsmen were quite simple, and did not appear to have any significant organizational capacities for system building. The craftsmen-based construction process seems to have dominated prior to WWII.

Even less is known about the rest of the residential construction industry. In the 1800s a majority of homes appeared to have been self-financed by the builder or homebuyer. "In 1890s only 28 percent of owner occupied, non-farm homes were mortgaged" (Doan 1997, 144). This compares to 63 percent of owner occupied homes that had a mortgage in 2003 (U.S. Census Bureau 2004a). In the 1800s, when external financing was sought, it tended to be from other individuals or through small scale, mutual savings banks and savings & loan associations. Lending was more informal and local compared to the

[39] Whitten and Adams implied that before WWII about 25% of homes were self-built in American cities (1931). In rural areas and in particular where homesteading was common, we can reasonably conclude that self-built housing had to be much higher if we accept the assumption that these areas had less access to skilled craftsman and investment capital. This claim is further supported by the popularity of sod homes (e.g., Goranson 1984), log cabins, stone houses (e.g., Jones 1970; Fife 1972) and other self-built houses made from whatever materials that happened to be in abundance (e.g., Calkins and Laatsch 1977).

highly institutionalized mortgage lending organizations of today that draw financing from capital markets around the world (Doan 1997, 144; also see Vill 1986). About the early realtors, appraisers, insurance providers, and the rest of the industry, little is known. However, given the informal nature of the earlier housing industry and the lack of a well-developed service and information sector of the economy in this period, it is likely that they played a limited or non-existent role in most markets.

Even though self-builders and small-scale, local craftsmen dominated the early 1900s, many critics referred to these organizational forms of construction as “obsolete,” “out of date,” and “primitive.” Residential construction was viewed as much less efficient than other industries. It was certainly true that the housing industry had a very difficult time keeping up with the demand for residential dwellings in many areas of the country. The critics suggested it was because the industry lacked the highly rationalized, vertically integrated, mass production processes of other industries that have achieved unprecedented economies of scale and levels of productivity. While these other industries were using task specialization, assembly lines, interchangeable parts, formal technical training, and sophisticated management hierarchies to coordinate different parts of the production process, the residential construction industry still used craftsmen to build houses, one-at-a-time, on the site of permanent foundations (McCutcheon 1992, 357; Doan 1997).

The critics asked (Corbusier cited in McCutcheon 1992): Why not mass produce housing at a central manufacturing facility and then ship the units to the market like other products? Since the 1840s or earlier, many firms were trying to do exactly that, but were not yet able to make a significant impact on the housing system. For example, during the California gold rush, prefabricated wood-framed dwellings were shipped to the San Francisco area from Monterey, California, and from as far away as New York, Philadelphia, Hong Kong, New Zealand, and Tasmania. Also, galvanized iron buildings were delivered from New York and Manchester and Liverpool, England (Peterson 1965). In New York City during the 1890s, concrete panel construction was used on a limited basis (Bender and Parman 1976).

One of the most successful pre-WWII efforts to industrialize a significant part of the construction process was by Sears, Roebuck, and Company. In the early 1900s the catalog company began to mail prefabricated home kits all over the country that arrived in 30,000 pieces. These were not shacks. They were well-designed homes with high quality components. The larger, more expensive styles were elegant town houses with gable roofs and dormer windows (Hicks 2000). “By 1908 the first catalog devoted exclusively to mail-order homes was issued. Entitled the ‘Book of Modern Homes and Building Plans’ it featured 22 styles priced between $650 and $2,500. These prices included plans, specifications, and most material down to the nails” (Stevenson and Ward 1986, 20).

The pieces of the kits were mostly precut lumber. To provide these pieces of lumber, Sears had invested in a lumber mill, a millwork plant, and lumberyard. Sears also provided mortgage credit in later years. Often homebuyers with little experience in carpentry assembled these homes, but still ended up with some of the best-built houses for the times. The quality was in the design and precut parts (Stevenson and Ward 1986, 20). In contrast to Swift or even or Singer, Sears did not, however, have to develop any new organizational capabilities for mass distributing and marketing their houses. Sears already had catalog sales and a marketing apparatus in place that uses the US postal service and railroad to make deliveries. This proved to be reasonable effective at delivering pre-cut home kits as well.

Between 1908 and 1940, Sears, Roebuck, and Company sold 100,000 mail-order houses. Sales reached their peak in the 1920s with about 3,000 sales per year and most were shipped to suburban areas of the United States. The company did well enough financially with mail-order homes in the 10s and 20s, but the same bane that now plagues the contemporary construction industry contributed to their demise—the cyclic economy. The production and selling of Sears and Roebuck home kits became unprofitable in the Great Depression and they drastically reduced operations. The production and sale of kit-homes was terminated in 1940 by the company (Stevenson and Ward 1986; Hicks 2000; Jandl and Stevenson 1989). The direct, lasting impact that Sears, Roebuck, and Company had on the residential housing system appears to have been minimal. By WWII, industrial housing only accounted for one-half of one percent of total housing construction (Keating 1972). However, the push for industrial building would continue.

WWII and Increased Federal Support for Industrial Building

WWII brought about a major housing shortage and a renewed interest in industrial housing—this time by the Federal government. When labor and raw resources were redirected to war production, there was a shortage of these inputs into the residential housing industry that was already having difficulties meeting demand. The rush of new workers to industrial centers also created higher demand than usual in many parts of the country. In an attempt to improve the efficiency of the use of labor and raw materials, the Federal government made its first significant effort to jump-start industrial building by underwriting a demonstration project in Maryland and by buying 116,000 units for federal housing around the country during the war (Bender and Parman 1976).

The end of the war triggered another shortage of residential housing, which was brought about by returning veterans that needed a dwelling. For a second time, the federal government decided to make a major effort to facilitate industrial building. This was the Wyatt Program under the Veterans Administration. Although it was post-war, the program was still able to invoke “emergency powers” to engage in the type of central planning that had occurred during the war. It used this power “to coordinate the housing and building material manufacture, allocate resources to residential construction, and underwrite factory production of housing by giving wartime plants and money to manufacturers [of residential housing].” This was a comprehensive, aggressive effort by the federal government that called for 2.7 million units in the first year, 1946, of which 800 units would be prefabricated (Bender and Parman 1976, 47; Office of Technology Assessment 1986b). Also, the federal government recruited only non-construction firms into the program because they thought residential builders were too primitive to learn industrial building.

However, the Wyatt Program largely failed to meet is objectives. Quotas went unmet, and over 70% of the 280 prefabricated firms in the program that started in 1946 had left the businesses a few years later. Several reasons have been offered. There was a break down in the coalition of federal agencies that the program was trying to coordinate in an effort to remove barriers to the industry; the conversion of war-time factories to peace-time manufacturing of houses prove more difficult than expected; and many lenders would not make VA mortgages for prefabricated housing or would complicate and delay the process (Bender and Parman 1976, 48). The non-construction firms did not live up to the federal government's expectations. While they were more sophisticated in the area of manufacturing, the participating firms were struggling in the housing industry with which they had no prior knowledge or experience (Office of Technology Assessment 1986b). Interest in industrial housing "simmered" down in the 1950s and 1960s and it was apparently because of these problems (Bender and Parman 1976, 48).

In the late 60s, there was another wave of industrial building. HUD engaged two different efforts to stimulate the industrial building of residential housing. Through its new "In-City" program, HUD sought to identify and remove impediments to increasing the volume of residential housing production and sponsored "demonstrations of experimental approaches to housing production." Then, HUD began "Operation Breakthrough" which was much more ambitious (Bender and Parman 1976, 48).

A much larger project, Operation Breakthrough was implemented when the Nixon administration took over the White House. Operation Breakthrough funded the development and demonstration of new housing systems on nine different sites. It again focused on the involvement of non-construction firms such as General Electric, Republic Steel, American Cynamid, Phillip Morris, AlCan, and Warner Communications. However, it made greater efforts to eliminate barriers to factory built housing. It tried with mixed success to improve marketplace acceptability, make building codes[40] and transport regulations more uniform, address union hostility, improve the lender acceptance of manufactured housing, ensure FHA approval of financing on a uniform basis, and aggregate the factory-built homes into sufficiently large markets suitable for the FHA's subsidized programs and purchase by the secondary mortgage market (Bender and Parman 1976; Doan 1997; McCutcheon 1992; Office of Technology Assessment 1986b).

After delays and much lower volumes than anticipated Operation Breakthrough completed its

[40] Anderson (1994) has also argued that widely varying building codes throughout the United States have created roadblocks to product standardization in the residential housing industry.

demonstration projects,[41] but it failed to substantially increase the market share of factory-built housing. A decade later, none of the firms that started with Operation Breakthrough remained to function as residential builders. Why? *First*, the Federal government lacked the long-term commitment to deploy the necessary organizational capacities for system building and to control and coordinate the parts of the larger system. Problem included a multitude of local building codes to which homes had to be built, and obtaining financing for the new technology. *Second*, as Bender and Parman (1976) commented, there was a cut in the overall program budget and half way through the program the federal government placed a moratorium on all subsidies for purchasing housing. *Third*, the federal government and the private firms had not been able to develop an infrastructure to cheaply transport factory built homes to the final sites where they would be installed upon a foundation. Reichley (1970, 4) states that at even moderate distances from a factory, the cost savings of mass production were overshadowed by high transportation costs. *Fourth*, Operation Breakthrough seemed to lack the kinds of focus that successful corporate R&D projects usually have by spreading out its resources over nine different building systems at different localities.

By the end of the 1970s, factory built homes were still essentially a failure in the market. Why was this so when manufacturing industries had been extremely successful at industrializing output and system building? Part of the answer has to do with the sociotechnical characteristics of residential dwellings that make them difficult to mass produce, distribute, and market that were mentioned above.

There were other problems that specifically had to do with a lack of organizational capacities for system building. *First*, there was a lack of control and central coordination. Historically, neither the government nor private industry has had the necessary control and centralized coordination of the various parts of the relevant system to successfully introduce something as complex as factory built homes into the market. While the federal government has had a fair amount of control over many aspects of the relevant sociotechnical system, it has not been centralized into one department, agency, or even level of

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[41] By 1972, Operation Breakthrough had only produced 26,000 dwellings nationwide at a cost to the government of over $72 million (Office of Technology Assessment 1986b).

government. The lack of coordination or cooperation among all of these government entities and private businesses has been a major problem. The sales of residential dwellings are extremely complex transactions that need assistance from an array of real estate professionals that, as a whole, make up a very fragmented, risk adverse set of economic actors. Getting the different professionals to forgo their own parochial interests and cooperate with the introduction of factory-made housing has been difficult. Historically, the three most problematic areas have been financing, codes, and transportation to dealers and to the final location of the permanent foundation. *Second*, the start-and-stop approach to system building by the federal government and participating firms has not worked. Organizational capacities were built up many times, and then left to flounder. *Third*, the federal government tried to build new a production system for industrial built homes almost entirely from scratch by recruiting manufacturing companies and additional firms from a wide variety of other industries. They usually did not ask existing residential builders to participate in the industrial building programs so that it could benefit from their existing organizational capacities and network relations.

However, in the last few decades, the industrial building movement has gained some momentum. According to the magazine *Automation in Housing*, about 200 plants were manufacturing modular homes in 1983 for an average of 350 homes per plant that were typically sold through dealerships (Office of Technology Assessment 1986d). In 1992, industrial builders completed about 5.19% of total housing units for the year including modular, panelized, and pre-cut homes. Modular had the largest share of these homes with 2.81%.[42]

Other nations such as the Soviet Union and Sweden have produced a large majority of their housing units through industrializing building. In part, this is probably because governments in socialist countries have had more central control and coordination over their relevant system. Indeed, through their large public housing sectors they were able to control and coordinate a larger number of the key players in their residential housing industries and obtain a fairly high degree of market penetration for industrial building (McCutcheon 1992). These key parts of the system include new home construction, transportation infrastructure, transportation regulations, building codes, home insurance, and mortgage finance.

Ironically, while US industrial builders largely failed, other parts of the US residential housing industry were able to achieve the goals of lower-cost and higher-quality housing. They were able to do so without financial support from the federal government. Specifically, after WWII on-site construction has become more factory-like and has managed to significantly reduce its costs (McCutcheon 1992). Also, by the 1960s the trailer/mobile home industry captured a large percentage of new home sales, and by 1982 it had 27% of the market for single-family homes.[43] Likewise, by the late 1980s mobile/manufactured homes were of similar if not higher quality than most on-site construction, and much more affordable.

Why were mobile home/manufactured housing firms able to achieve what industrial builders were not? Part of the reason is that the federal government tried to build entirely new system of mass-producing residential construction. They did not try to build upon the existing organizational capacities and systems arrangements within the existing construction industry or in the trailer/mobile home industry whereas trailer/mobile home manufacturers continue to expand their organizational capacities and engage in continual development of their product into manufactured housing. Although the manufactured home industry's share of the market has fallen to 9.04% in 2003, it apparently has not been because of competition from the industrial building of modular homes but instead from more efficient production builders. These issues will be discussed in the next two sections.[44]

Comparison of Manufactured and Modular Housing

In the last decade or two, manufactured and modular homes have become indistinguishable from each other to the untrained eye once installed. However, they are slightly different technologies. *Modular* homes are dwellings that have been manufactured by contemporary industrial builders, and that are built almost entirely in factories through an assembly line process. These are then shipped to a final location as

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[42] Numbers were calculated from data collected by the U.S. Census Bureau (2004i) and U.S. Census Bureau (2004j).
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one or more modules to be assembled where they are assembled and attached to a permanent foundation. These must comply with the building codes of the local jurisdiction. Single modules are quite common, and mostly ready to be occupied as soon as they are set on the foundation. Occasionally, siding and parts of the roof are installed on site.

Manufactured houses are also made in centralized, mass production facilities, but firms that make them grew out of the firms that made mobile homes and trailers. More recently, these dwellings have been called "HUD code homes" because the construction of these is now regulated by Department of Housing and Urban Development instead of through local building codes. Just like the travel trailers of the 1930s and more recent mobile homes, these manufactured homes have a permanent axis and wheels, although the wheels can usually be removed and the dwelling attached to a permanent foundation. Historically, the firms that make manufactured homes have been different from those making modular homes.

Since the 1920s, the industry that would become the manufactured home industry was producing and shipping their "trailers" to regional and national markets. Trailers were "considered as both a vehicle and a residence," and they were taxed as personal property instead of real estate. They were financed like automobiles, but owners could purchase homeowner insurance although at a higher rate (Hart and Morgan 1980). These dwellings/vehicular accessories were intended for recreational purposes, and were purchased as such by the upper and upper middle classes.

Historically, low-income families commonly used the 8' by 25' travel trailers as permanent dwellings. By the 1930s, trailer parks were becoming a dominant part of U.S. culture, and started to gain their unsavory image as being associated with poverty (Hart and Morgan 1980). To respond to the growing demand in the 40s, 50s, and 60s, thousands of small firms sprang up to make "trailers" for local buyers, and resulted in a very fragmented set of small firms. Start-up costs were very low for trailer makers, and few had much sophistication or specialized equipment (Hwang 1982).

In the 1950s, the trailer manufacturers realized that they could sell more of their product if they redesigned it to better fit with the changing market for their product. They redesigned their trailers to be more like conventional homes with common accessories and more space. They also renamed their product in 1954. A manufacturer made a ten-foot wide trailer, and discovered that a typical family car could not pull it. It boasted that it was actually a “mobile home” not a trailer (Hart and Morgan 1980).

Mobile homes were larger and more home-like, but still had negative connotations and within industry and government there was a push for quality and safety. In 1976 with promulgation of the Manufactured Home Construction and Safety Standards Act mobile homes were regulated as residential dwellings by the Department of Housing and Urban Development (HUD). Shortly after that, the term “manufactured housing” was codified by another piece of legislation entered into common usage. The industry thought that changing the name to denote a more permanent, conventional dwelling would boost sales. The average manufactured home is now almost as large as the average site-built home, and most will never be moved from where they were initially installed (Hart and Morgan 1980).

In the 60s, 70s, and 80s, makers of manufactured homes were growing larger, more sophisticated, and capital intensive. In 1983, the largest homebuilder in the nation was actually a maker of manufactured homes, Fleetwood Enterprises, and produced almost 38,000 units that year. Firms located branch plants and dealerships close to distant markets. This production, distribution, and marketing strategy allowed them to sell much larger homes to regional and national markets (Office of Technology Assessment 1986d; Hwang 1982; Hart and Morgan 1980). The Manufactured Housing Institute estimated that in 1983 about 185 U.S. firms shipped manufactured homes from 410 factory sites The average number of units per plant was 582, which is a considerably higher volume than the average on-site builder (Manufactured Housing Institute 2004).

Over the last decade, firms that made manufactured homes averaged a combined market share that has been about 5 times higher that modular construction.[45] and has done so with relatively little assistance from the government and in the past has had to contend with considerable animosity by local jurisdictions over trailer parks.

[45] Numbers were calculated from data from the U.S. Census Bureau (2004i) and U.S. Census Bureau (2004j). However, in the last decade the share of market held by the manufactured home industry has fallen to 9.04%.

Modular homes have not competed as well despite the similarities in function, appearance, and price. Why has this been the case? Why did manufactured housing rather easily capture a fairly large share of the total housing market when industrial builders struggled for a smaller share even after significant government assistance? There are four interrelated answers to these questions, of which the middle two are explicitly about system building. *First*, early manufactured home firms did not have to comply with widely varying local building codes because they were not technically considered residential dwellings until the mid 1970s. This allowed them to more efficiently target a larger market than the builders of site-built homes. Moreover, because they did not have to worry about different codes at each locality, it was much easier for them to sell to a mass market than it was for industrial builders. Industrial builders had to deal with selling to tens of thousands of different code enforcing jurisdictions (Building Research Board 1992; American society of Civil engineering. 1995). *Second*, the industry had a set of organizational capacities to manufacture, distribute, and sell trailers that were very adaptable to the production of mobile homes and then manufactured housing. Most importantly, these manufacturers had a distribution system already in place that gave them access to mass markets, which made larger economies of scale possible. *Third*, early financial success allowed them to invest in additional system-building activities markets, such as multi-plant production strategies, dealerships to reach a much larger market, and a rather continuous process of product development to fit their product into a changing market. *Fourth*, when manufactured homes were finally regulated, it was through a uniform national standard that allowed access to essentially the same mass market as they had before. In contrast, modular homes still had to sell to local markets with a wide variety of building codes.

It was mentioned that the organizational capacities of the trailer firms contributed to the success of mobile home and manufactured home sales. While accurate, the capacities of the trailer firms were nothing very sophisticated or extensive, but then neither were those of firms that constructed site-built homes. Instead, the advantage to the making and selling of mobile and manufactured homes appears to have been that the production, distribution, and marketing capabilities of “trailers” were easily adapted to making and transporting of “manufactured homes” from a centralized facility to permanent locations

(Hwang 1982; Hart and Morgan 1980). The concept of chassis and wheels for the trailers were also used for mobile and manufactured homes, and it was little problem to deliver them five hundred or sometimes even a few thousand miles. Also, the industry already knew the road system, each states traffic regulations, and what size and shape of trailers/homes that each road could handle (Hwang 1982; Hart and Morgan 1980). Likewise, their use of branch plants and dealers that were close to distant markets was important. Studies in the southeastern United States in the 1970s found that 85% of a firm's mobile home sales occurred within 300 miles of a manufacturing plant (Knight 1972; Wheeler et al 1974; Wheeler 1976).

In fairness, it should be mentioned that government did assist the mobile/manufactured home industry when it changed traffic regulations to make transportation easier and when it created an uniform national code to regulate them. Also, in the 60s and 70s, the Federal Housing Administration and Veterans Administration allowed mobile homes to be financed and insured through the Federal government to address a large unmet demand for financing and insurance. Private business soon entered the market as well (Hwang 1982). However, this appears to have been more if the case of the government responding to the new problems created by a successful technology rather than the government trying to jump-start a troubled industry as was the case with industrial builders.

Conclusion

The unique characteristics of the residential housing system have historically made system building difficult. The characteristics of residential dwellings as heavy, bulky, and technically and socially complex artifacts have not made them amendable to centralized mass production and its associated organizational complexity. Thus, the large, complex, organizational structures that can be very useful for system building have often not developed.

Despite the unique characteristics of the industry that make doing so difficult, firms have sometimes successfully engaged in system building. However, in most cases the system building efforts originated came from outside of the residential housing system, and thus were not entirely constrained by a lack of organizational capacities within the industry. Firms that make trailer/mobile/manufactured homes are one such example. Indeed, these firms brought an entirely new process of building residential dwellings to the mainstream residential housing industry. The system building did follow approximately the same path as discussed in Chapters 3. The industry did engage in substantial horizontal integration and the development of dealerships that is roughly comparable to that described for many companies in Chapter 3. However, the industry does not appear to have developed the R&D capacities to control the direction and pace of technological change that was discussed in Chapter 4. One key to their successes appears to have been starting out in a niche market for travel trailers that was outside of the housing industry and then diversifying into affordable permanent dwellings within the housing industry. This was another niche market where there was little competition in terms of price from conventional site-built construction. This allowed them to amass capital, grow in size and sophistication, and eventually directly compete with the on-site construction in the main stream real-estate market.

Other attempts at introducing new highly systematic innovations into the residential housing system have been much less successful. Despite the considerable resources and organizational capacities of the federal government, its involvement did not seem to provide much help for the building industry. The lack of strategic focus and coordination and the politicizing of the system-building process appear to have been sources of problems.

Chapter 7: New Home Side of the Residential Housing Industry

This chapter will assess the organizational capacities and overall structure of new construction in the current residential housing industry. There have been some significant changes over the last half century. Home construction is no longer craft-based. Instead of the generalist craftsmen of the pre-WWII era, residential dwellings are now assembled largely by semi-skilled and unskilled labor from prefabricated components and pre-processed building materials, and the industry has experienced a division of labor into specialty trades that operate as contractors and subcontractors.

Organizationally, the construction firms in the residential housing industry are at approximately the same level of development as manufacturing firms were in the late 1880s—mostly small firms in a highly fragmented industry, with little ability to engage in their own R&D and marketing. In general, these firms appear to have little or no organizational capacities to exert for significant impact on the direction or pace of technological change or engage in other types of system building. Although some residential builders are becoming larger, they are still small by the standards of the larger economy. The pattern of growth is similar to that of firms in the late 1800s. Some or perhaps many of the production builders that have been joining with other builders or specialty firms have been doing so by consolidating under the umbrella of holding companies. It appears that these firms are seeking the benefits of legal integration, such as using a single brand name for regional or national markets, and foregoing managerial integration for the time being. As I will discuss, production builders' capacities for system building appear to be greater than most small builders, though they are still rather limited.

The holding companies of production builders could prove to be stepping stones for more sophisticated organizational forms with substantially more powerful organizational capacities for system building. This was the case for manufacturing firms in the late 1800s.

On-Site Construction

To the surprise of many, on-site builders over the last half of a century have been able to accomplish much of what industrial builders have been unable. Although the factory-built homes (e.g., modular and panelized) have been slow to gain popularity, on-site construction by conventional builders has come to resemble factory work resulting in improved quality, cost savings, and faster construction times. This has primarily been due to autonomous innovations such as prefabricated components, power tools, and various construction techniques. It has not been from following the path of vertical integration and R&D that most other industries have pursued. Even though there has been some horizontal and vertical integration, most builders have remained relatively small with few capacities for system building.

I want to elaborate on how these changes occurred. Since WWII craft-based construction has been largely replaced by new technologies and ways of structuring construction work that represent significant changes over the last 50 years. Builders and subcontractors now purchase prefabricated components and processed materials instead fabricating and processing them on site. This includes wall frames, floors, trusses, gables, kitchen and bathroom units, glues, varnishes, paints, fillers, sealers, and insulation (see Doan 1997, 144). Up to 40 percent of all U.S. residential dwellings are built in whole or in part using factory-built components that are delivered to a construction site according to the Building Systems Councils (Marino 1997). Also, machine tools have replaced most hand tools with powered nail and glue guns, electric saws, routers, paint sprayers, and sanders that allowed relatively untrained and unskilled labor to efficiently assemble prefabricated parts and pre-processed materials.

Likewise, the organization of the on-site construction process has changed. Instead of generalists who completed the entire building process on their own, builders subcontract out to specialists who now dominate the industry. As builders began to incorporate high-tech subsystems such as electrical, heating and cooling, and plumbing, there became a greater need for even more specialization to install these more complex parts and subsystems. Other common specializations include framing, roofing, insulating, laying tile, laying floor and wall coverings, dry walling, and finishing.

High-volume, production building and product standardization have become very common. Although there were only a few hundred firms that classified as production builders (over 100 units per year), these firms accounted for approximately 40% of all single-family residential dwellings that were built by professionally builders[46] according to Rappaport and Cole (2000). Some of these production builders have become quite large and appear to have increased their organizational sophistication through professional management, horizontal integration, and some vertical integration. In a factory-like process, production builders construct a limited number of designs in large volume (a dozen to a 1000 homes at a time) on single tracts of land. Instead of using conveyor belts to move their product from workstation to workstation as in a factory, production builders will move subcontractors, their equipment, components, and supplies from one house to the next in an assembly line fashion to build nearly identical dwellings.

While production building has in most ways increased the organizational sophistication of the industry, the amount of horizontal and vertical integration is still small compared to most industries. Also, the on-site construction process is more organizationally fragmented than the construction processed used by smaller builders. Large production builders have relied even more heavily on subcontractors than smaller firms.[47] Bashford (2002) commented that few general contractors who start more than [50] homes per month actually perform any construction work, and instead rely on nine or more subcontractors for site preparation, construction of these dwellings, and landscaping. This is likely to have made it even more difficult for these large builders to coordinate subcontractors in pursuit of system level goals such as the introduction of systematic innovation (Mullens and Hastak 2004).

Despite these developments, the organizational structure of the new home side of the housing industry has changed very little relative to most other industries. Although since WWII the residential housing industry has been able to produce higher quality, cheaper, more sophisticated homes and in less time than critics thought possible, the gains in productivity have mostly come from the use of new building

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[46] The data by Rappaport and Cole (2000) only included professional builders who are general contractors with employees who focus on the new, single-family construction. It excludes owners that built their own house, firms such as remodelers and specialty trades that sideline in new, single-family construction, general contractors without employees, and other entities that are on the margins of new, single-family construction.

[47] Some firms perform almost all of their construction work in-house. However, other builders only operate as a general contractor and subcontract out all of their work without ever picking up a tool. The statistics by Rappaport and Cole (2000) suggest that the size of the firm (measured by the number of housing starts in a year) is a determining factor. For general contractors specializing in residential construction and that started between 1 and 4 single-family residential housing units in 1997, they subcontracted out 30% of the dollar value of the construction work that they put in place. In contrast, the same type of firms that start between 100 and 499 houses per year subcontracted out over 43% of the value of construction work on average—almost a 50% increase in volume in

techniques, pre-fabricated parts, and power tools. Changes in the organizational structure have played a minimal role in these improvements (Haas et al. 1999). This is in contrast to manufacturing industries where the increased efficiency, quality, and sophistication were possible through mass production that in turn prompted changes in the organizational structure such as vertical integration; changing from owner-operated, small businesses to professionally managed multidepartmental organizations; and a significant investment into management hierarchies that can coordinate complex production processes and capture economies of scale.

Below is a fairly detailed description of the new housing side of the residential housing industry, including builders as well as other firms such as realtors and mortgage lenders. Overall, the residential construction industry remains very fragmented and dominated by small builders who have little or no organizational capacities for system building. Most of the builders and other firms in the industry use a small business model of organization where the owner/manager directly supervises most tasks. Approximately 85 percent of all residential construction firms[48] that have 9 or fewer employees (U.S. Census Bureau 1999b), and most of these operate in one local building market. The large production builders and their increased organizational sophistication are still a minority.

Organizational Structure of On-Site Builders

Many small firms are amateurish and often dabble on the edges of the industry. Firms and individuals who were not professional builders of single family homes or did not make most of their income from this activity constructed approximately 277 thousand single-family homes out of the total of about 1,133 thousand in 1997. Of these 277 thousand starts, 130 thousand were self-built by homeowners or homeowners acting as their own general contractor. Another approximately 200,000 housing starts were by small, general contractors or by speculative builders without employees (most of which were likely remodeling and specialty trade firms moonlighting as builders). The remainder was built by owners for lease or rent (Rappaport and Cole 2000). Many of these builders were able to join the industry

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subcontracting by the largest builders.

because of low capital costs and minimal or no educational requirements.

Mainstream professional builders that specialized in single-family homes also tend to be small. Professional builders were responsible for 856,000 housing starts out of the total of 1,130 thousand in 1997. Approximately 94% of all professional builders started 25 or fewer homes in 1997. These smaller professional builders were responsible for only 39% of the total starts by professional builders. Those professional builders that started at least 25 but less than 100 homes were responsible for the next 21% of starts, and they represented 4.7% of the firms in the industry (Rappaport and Cole 2000).[49]

There are, of course, larger construction firms in the residential housing industry. However, in 1997 only 232 residential builders out of 138,850 had 100 or more employees and were capable of constructing a few hundred homes per year. Only 10 of these builders had 500 or more employees and were capable of constructing ten thousand or more homes (U.S. Census Bureau 1999b). This small number of largest builders constructed the largest portion of homes in the industry. Rappaport and Cole (2000) noted that the top 0.2% of the US professional building firms in 1997 (which was 152 firms) accounted for 16% of the total number of single-family residential homes that were started. The top ten builders in 2003 were D. R. Horton, Pulte Homes, Lennar Corp., Centex Corp., KB Home, Beazer Homes USA, The Ryland Group, NVR, Hovnanian Enterprises, and M.D.C. Holding. The largest, D. R. Horton, had a sales volume of $9.2 billion dollars, and the top ten were over $2 billion (Builder Online 2005).

Vertical, horizontal, and other types of integration have become more common among larger builders. The top-ten largest builders “doubled their market share over the last 5 years, jumping from about 11 percent of all sales in 1997 to 23 percent in 2003” (Sichelman 2004) largely through mergers and acquisitions and also internal growth, which has resulted in large economies of scale (Heavens 2002; McCune 2000). The largest builder, D.R. Horton of Arlington, Texas has combined with seventeen other firms since 1994. Pulte Homes of Bloomfield Hills, Michigan, the second largest, acquired six firms since 1993. The third largest, Lennar Corp. of Miami, Florida, added 23 firms, as shown in Table 7-1.

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[48] This statistic is for construction firms that have a payroll.
[49] Again, the data by Rappaport and Cole (2000) only included professional builders who are general contractors

Table 7-1. Number of Acquisitions by top 15 builders: The data covers the years from 1993 to 2005 (January to March).

Rank by # of housing units sold in 2005	Builder	Number of Acquisitions and mergers	Publicly traded or privately owned	Building America partners or Energy Star participant
3	Lennar	23	Public	BAP/ES
1	D.R.. Horton	17	Public	BAP/ES
5	KB Home	14	Public	BAP/ES
8	K Hovnanian	13	Public	BAP/ES
6	Beazer	12	Public	BAP/ES
4	Centex	11	Public	BAP/ES
11	Standard Pacific	9	Public	ES
12	Technical Olympic	7	Public	Neither
9	MDC (Richmond American)	6	Public	ES
13	Meritage	6	Public	ES
2	Pulte	6	Public	BAP/ES
14	Toll Brothers	5	Public	ES
7	Ryland	3	Public	BAP/ES
15	Shea Homes	3	Public	BAP
10	NVR/Ryan Homes	2	Public	BAP/ES

(Source: Adapted from Ahluwalia 2005)

Many of these horizontal mergers have been into holding companies that involve only legal integration of ownership. This is similar to the majority of mergers in the latter half of the 1800s. However, the reasons for seeking legal integration are different. Instead of wanting to avoid predatory trade, the motivations of these holding companies seems be other benefits of legal integration, such as using the same brand name for their homes on a regional or national housing market.[50]

Just as builders have grown in size, so have subcontractors and other types of firms. Large builders need large subcontractors that can conduct their specialty trades in higher volume to install insulation, wiring, and plumbing than the traditional mom-and-pop operations are able.[51] However, these subcontracting firms still have been rather small and as a whole constitute a very decentralized industry.

with employees who focus on the new construction of single-family homes. Refer to footnote 18.

[50] An examination of the web pages of most of the top 20 builders in the United States showed this to be fairly common. However, the analysis did not allow for accurately determining the percent of builders that are organized into holding companies.

[51] Mike Stranethan, owner of National Insulation, July 2000.

The smallest 94% of firms (with sales under $1 million) with employees[52] that specialized in *framing* controlled 37% of the total 15 billion in sales for this group firms in 2002. The remaining 6% of firms (800 businesses) controlled the remaining 63% 0f sales. Of businesses that specialized in *drywall and insulation*, the smallest 86% of these firms (sales under $1 million) controlled 28% of the total sales. The remaining 14% of firms controlled 72% of the total $31 billion of sales. The top 14% of the firms numbered at 2,700. For those specializing in *plumbing and HVAC*, the smallest 90% of firms (sales under $1 million thousand) controlled 34% of the total sales. The top 10 % (8,900 firms) controlled 66% of total sales (calculated using data from the U.S. Census Bureau 2004m, 2004n, and 2004o).

Actually, the mortgage lending business has become one of the most sophisticated, centralized, horizontally integrated firms in the residential housing industry. There are still many small firms that originate mortgages, but essentially all of the money that is lent and that is used to insure mortgages is provided by very large banks that operate in national and international finance markets. In the last few decades, mortgage lending has seen even more consolidation (see Doan 1997 for similar comments).

The manufacturers of construction inputs have also become highly concentrated even by the standards of the rest of the economy. The four largest firms in the following product lines control between 92% and 40% of the market. These products are refrigerators, washers and dryers, flat glass, sheet rock, vitreous plumping fixtures, ovens, structural clay products, particleboard, construction machinery, woodworking machinery, and softwood plywood (U.S. Census Bureau 1982). However, construction inputs are only one product line for these firms, such as 3M and Dow Chemical.

Except for the largest builders of single-family homes, the amount of vertical integration among residential construction firms appears to be negligible. Most on-site construction firms have not significantly integrated into down-stream manufacturing of construction inputs. Likewise, upstream integration has also been rare to selling real estate. Most firms do not even have their own purchasing departments but instead they must buy components, materials, and supplies from the local building supply

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[52] Many contractors are operated by a sole-proprietor without employees, and they subcontract all the work or conducted it by their selves.

store (Ehrenkrantz Group cited in Slaughter 1991).

However, as mentioned, large production builders have integrated and diversified into numerous business lines that have synergies with home building. The buying, developing, and selling of land accounts for about $65 billion of $148 billion of total construction work among firms specializing in single-family residential housing (U.S. Census Bureau 1999b). Also, it is common for larger builders to be vertically integrated into purchasing, into the marketing and selling of their products, and diversified into mortgage financing, title services, and home insurance[53] (Lycos Financial 2005).

However, the “integration” seems to usually be in the form of holding companies. In most cases, these capabilities exist in the form of subsidiaries of a larger holding company, and do not share a common management structure with the production builders. The top ten production builders in 2003 were organized in this manner (Lycos Financial 2005). However, most builders and particularly the smallest builders are reliant on external firms for developing sites and selling their finished homes. It is also common (but not necessarily a new development) for larger residential builders to have their own design capabilities even if it is often only a draftsman. Most homes are completed without the skills of architects who usually work with custom builders who are constructing homes for higher income customers (Slaughter 1991).

Other types of organizational integration appear to be rare. Residential builders rarely, if ever, have their own R&D capabilities, which will be separately discussed below. It also appears very rare for builders to integrate into the production of downstream tools, materials, supplies, and components that are used in construction.

Also, there are three common kinds of product diversification in the industry. These are product-related diversification, geographical diversification, and also product-unrelated diversification that appear to have benefited firms in a number of ways. According to data provided by Rappaport and Cole (2000), 56% of professional builders that focus on single-family housing are diversified into *related* activities,

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[53] Conversations with industry participants and a scan of the web pages of some of the largest production builders

such as working as a remodeler, working as a subcontractor for another builder, or constructing either multifamily housing or commercial buildings.[54] *Geographical* diversification is only enjoyed by the largest builders in the industry that can operate in regional or national markets. If the market deteriorates in a few localities but retains vigor in others, the company may not face a devastating decline in sales. Likewise, if there is a surge in market activity in one locality, the firm can shift staff and equipment to that market. Also, it is common for larger production builders to *diversify* into unrelated[55] products and services, such as mortgage financing, title services, land development, and home insurance[56] as part of a system-building strategy to expand into products and services that have synergies with home building. Also, it allowed them to offer customers one-stop shopping and affordable package deals, and to capture more profit from the same homebuyer. It can take relatively little additional effort to sell mortgage products and title services since the builders already have easy access to homebuyers. Usually these diversified services are offered through subsidiaries[57] that are likely to offer the production builder less control than using management hierarchies.

Firms in the residential construction industry can also be differentiated according to the markets in which they sell. The price of residential dwellings is likely the most important market characteristic of new construction, and it appears to influence how on-site builders organize their construction process. Firms usually refer to themselves as either design-build (custom builders) or production builders.

Design-build firms, sometimes called customer builders, cater to buyers who are willing to spend money on custom design and construction, as well as larger homes and more craftsmanship, quality, and amenities. Often these customers will already have their own land and financing when they contact a design-build firm. Customers will use the design capabilities of the builder, or they will hire an outside

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confirm that this is common among the largest production builders.

[54] Again, the data by Rappaport and Cole (2000) only included certain professional builders. See reference 18.

[55] These are considered unrelated in the sense that that it takes very different organizational abilities to provide these mortgage products and title services than it does to construct housing.

[56] Interviews with industry participants and a scan the web pages of the largest builders suggest that this form of diversification is quite common among the very large builders.

[57] A scan the web pages of the largest builders suggests that these diversified services are offered through subsidiaries.

architect. Sometimes the design capabilities of design-build firms will be staffed an architect. Design-build firms will construct up to a dozen or perhaps a few dozen homes per year.

Production builders usually focus on affordable new housing for first-time homebuyers and for working and lower middle class buyers (although some have expanded into higher-end markets). They keep costs low through building a high volume of a limited number of models. Product standardization and volume building helps keep design, land, material, and labor costs low. According to a builder in Lincoln, Nebraska, it is much easier to organize and oversee subcontractors when a firm builds to a limited number of plans. Often builders will construct row after row of homes on a single piece of land, and then move laborers and materials down the rows in an assembly line fashion. It has also been suggested that the largest of the production builders have additional significant advantages over the regional and local builders. These include lower capital and operating costs, cheaper access to land, purchasing materials in very large quantities, and powerful brand names. If we define production builders as those that build 100 or more units per year, then 40% of the homes constructed by professional builders of single-family homes that were started in 1997 were made in roughly this fashion (Rappaport and Cole 2000, and also see Sichelman 2004).

There are different types of contractual arrangements between buyers and sellers that include self-building, custom building for buyers, and building for speculative buyers. S*elf-builders* will often act as their own general contractor and negotiate numerous contracts with subcontractors. Self-builts accounted for 123,000 housing starts in 2002. Contractors build many more homes for sale on the *speculative market*. These are often called spec built homes, and totaled 967,000 home starts in 2002. In the same year, 195,000 homes were built by *general contractors at the homebuyers' request* (U.S. Census 2005). A large majority of these general contractors were probably design build firms. However, there is not always a clear difference between the homes built for the speculative market and those built by general contractor at the homebuyer's request. Homes intended for the speculative market are often purchased by customers prior to completion, and then builders offer as much customization as possible.

There are also common types of building systems. The most common on-site ones are design build, production building, and the use of prefabricated components, as well as a few less common systems. The *first two* building systems were, of course, mentioned above. The *third* refers to the extensive use of prefabricated trusses, walls, and floors in on-site construction that occurs in perhaps 40% of all new construction (Building Systems Councils cited in Marino 1997). However, none of these three represent a clear cut building system. Design build and production building exist in a continuum, and either can make extensive use of prefabricated components. There are other less common on-site construction systems that use alternative structural materials. *Fourth* and *fifth*, there are straw bale (concrete and straw bales) and insolated-concrete-form construction technologies (concrete and foam insulation) that have been viable as a commercial technology in only a few local markets.

There are of course off-site, industrial building systems, and these are homes that are significantly fabricated and/or assembled in the factory and shipped to site for final assembly or installation. *Sixth*, of industrial built homes, only the *HUD code homes* have obtained a market size that has had an impact on the industry, and *seventh* there is the *modular* building system as mentioned. However, there are other building-systems that rely on a large number of components that are extensively pre-fabricated and pre-assembled that are shipped to the site and put together.

Ninth, there are, of course, a number of other building systems that sell to even smaller niche markets, panelized housing construction, precut lumber (e.g., log homes), and geodesic domes. Of these, I will only elaborate on panelized systems. *Panelized* homes are almost completely built from prefabricated components that are shipped to the site of a permanent foundation where they are assembled and attached the foundation. Panelized builders are able to take an architect's plans, build to them, and conform to code. Floor panels are attached to the foundation, and then mechanical cores are attached to that. These cores are "little self contained buildings" that include "one or two bath rooms, the furnace, the hot water heater and usually the electrical junction box." The interior and exterior wall panels then go up around mechanical cores. These wall panels usually come with exterior sheeting, pipes, electrical wiring and fixtures, and insulation, and are often mostly finished on the interior. The one or more pieces of the roof are then attached (Carlson and Dluhosch 1982, 49). Again, in the real world there are not always clear differences among these building systems.

While most residential builders use only one of these building systems, some firms use two or more construct residential dwellings. In 1983, five of the twenty-five largest builders of residential homes were diversified into two or more of production building, panelized systems, modular homes, and/or manufactured homes (Office of Technology Assessment 1986d).

Organizational Capacities for System Building

Here we will explore and discuss the extent to which residential construction has the five organizational capacities for system building. These are, of course, financial resources that can be flexibly deployed, control, information, central coordination, and centralized planning, which will be evaluated for the residential building firms in this section.

Access to *financial resources that can be flexibly used* for system building is crucial if organizations are to acquire additional capacities and then use them for actual system building. For the small firms that dominate the industry it can be difficult if not impossible to acquire these financial resources. However, residential construction firms are getting larger, and in the last two decades many of them have become large enough in size where they are now making significant investment in centralized, mass-production facilities and R&D (Office of Technology Assessment 1986c; 1986d). Several options are available depending on the size and sophistication of firms.

If retained earnings are available, internal financing of system building is the most affordable, no-strings attached way to finance system building. This is the most common way to fund the initial stages of high-risk system building such as a R&D program (Himmelberg and Petersen 1994) because outside investors are often not interested in such risky endeavors. However, small firms, which make up a majority of the residential builders, do not have a sufficiently large, dependable stream of profit from which earnings can be retained for long-term, risky investments (Building Research Board 1988). For example, consider a small production builder—a firm that has 32 employees and builds 192 houses per year for 24 million dollars in value-added construction work (which would be larger than 98% of other builders).[58] It could take a 35% increase in their budget for even a small R&D program with five researchers, three marketers, and an advertising budget. As stated by the Building Research Board (1988), such added expenses would be impossible for most builders.

Internal financing of ambitious R&D projects is possible for the largest residential builders. There are a dozen or more builders with about 1,000 employees, tens of thousands of home starts, and billions of dollars in revenue per year. A firm in this size range could likely afford an R&D program and marketing effort of significant size from retained earnings. However, the reality for most builders is that if they want to engage in significant system building, they need to seek external sources of financing. "Finding a source of capital to finance company growth can be a major challenge, particularly for small and midsize businesses in such sectors as . . . residential construction" (Orlandella 2004). There are a few options, which include borrowing money from commercial lenders, selling stocks, and venture capital.

While venture capital has become more widely available to small firms in the last few decades (Kortum and Lerner 2000), venture capitalists do not appear to have yet taken significant interest in the construction industry.[59] At intermediate and latter stages of technological development and system building in other industries, venture capital is often use by young firms without equity that are engaged in risky system-building activities with the potential for large earnings.[60] These lenders usually do not require equity, but they do ask for a share of future profit. Even when available, venture capital is expensive.

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[58] Calculated from data in Rappaport and Cole (2000) and U.S. Census Bureau (1999).

[59] The National Science Foundation, which collects US statistics on the use of venture capital did not find the level of venture capital in the construction industry to be high enough to create a separate category for the construction industry (National Science Board 2004). Instead, as noted by the (National Science Board 2000), venture capitalists have sought out high tech industries such as biotech, telecommunications, computer hardware and software, and health care that have demonstrated their prowess at R&D and making highly profitable innovations. This has not historically been the case with residential builders or the construction industry in general.

[60] Very little venture capital is actually used in the inventive process to prove a concept. Most of it is used in latter stages of product development and then especially in the expansion and elaboration of proven product lines. "only a relatively small amount of dollars invested by venture capital funds ends up as seed money to support research or early product development. Seed-stage financing never accounted for more than 8 percent of all disbursements over the past 23 years and most often represented between 2 and 5 percent of the annual totals" (p. 6-31). In 2002, seed financing accounted for only 1% of total venture capital. Product development accounted for 19.8 percent of the total. The expansion and elaboration of market proven product lines through internal expansion, acquisitions of other companies, leveraged buyouts, and other activities accounted for the remaining 79.2 percent (National Science

In latter stages of system building, such as to expand production and marketing abilities of proven product lines and/or when firms are mature enough to have significant equity, commercial bank loans that require equity are more commonly used. However, this type of financing typically comes with strings attached. The borrower often will not be able to use the financing exactly as she or he chooses because "investors will want a say in how the business is run" (Orlandella 2004).

For residential builders that are publicly traded companies, selling stock is good option for generating investment capital. The top-ten largest production builders in 2003 were all publicly traded companies that sold stock to finance long-term system-building activity, and there are more than dozen other builders that are publicly traded.[61] Some of the top-performing stocks have been in the residential construction industry (Anonymous 2004) suggesting the ability to use the stock market to generate investment capital for system building. Of course, most residential construction firms remain too small to do so.

For small residential builders without much equity or a track record of success, institutional lenders, venture capital, and the stock market are unlikely options. As Himmelberg and Petersen (1994) noted, unless a loan is secured with equity, banks are usually unwilling to lend money for risky, long-term investments to firms. Also, firms are leery about leveraging parts of their company for high-risk endeavors, and understandably so. Likewise, a large volume of stock buys tends to follow success, not jump-start it.

There are still other options for some types of system building. Mergers and leverage buyouts allow small, capital-starved firms to combine with little or no financing, and are only limited by the speed at which they can negotiate deals, pay legal and consulting fees, and restructure management. A dozen or so production builders have become the largest in the industry through these acquisitions and mergers. However, there are real and significant limitations to acquiring capacities for system building through mergers and buyouts. If, for example, there is not a construction R&D lab that is looking to be purchased

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Board 2004).

[61] The top ten builders in 2003 were D. R. Horton, Pulte Homes, Lennar Corp., Centex Corp., KB Home, Beazer Homes USA, The Ryland Group, NVR, Hovnanian Enterprises, and M.D.C. Holding (Builder Online 2005). A scan of these company's web pages indicated their status as a publicly traded company. Also, there were a total of 23

or bought out, then the residential builder must develop his or her own internal capabilities, which, as discussed in Chapter 4, is much more difficult and time consuming.

To *control* the parts of its relevant sociotechnical system, an organization has two general approaches it can take. It can internalize these parts into its internal management hierarchy, or it can assemble the internal organizational capacities such as marketing to exert control and influence on the external parts of the system. However, most builders, and even the larger ones, do not have the internal management hierarchies to directly control the relative parts of their sociotechnical system nor internal organizational capacities to exert dependable control over most parts of the system that are external to their organization.

Most builders do not have a purchasing department to obtain inputs directly from factories nor do they have storage facilities to keep inventories. Problematically, they must rely on local building supply stores for the timely delivery of these materials to the construction site in the quantity and quality needed, and are limited by what their suppliers keep in stock (Ehrenkrantz cited in Slaughter 1991). Tucker (1984) stated that labor was idle over one-third of the time, in part, due to problems coordinating the flow of materials to the job site. For unusual components, materials, or supplies that might be needed for new innovations, local building supply stores may have an even more difficult task delivering them in a timely manner. For example, dual pane windows must often be specially ordered and can delay deliver by a week or more (Federal Energy TEEM 2002), which can be unbearable to a builder on a tight schedule.

The supply of labor is similar. Most residential builders have little control over the labor market from which they drawn upon for in-house construction workers. As mentioned, particularly during up-turns in the market, builders will often have difficulty finding skilled workers. The large, national and regional builders likely have an advantage here. To some degree, they can shift labor from localities were demand lags to localities where demand is stronger. While much of the construction process has been deskilled in recent decades, there is still the need for well-trained construction workers who understand how to correctly install components and materials in order to build energy-efficient, high quality homes. Subcontracting makes it even more difficult to control labor. In particular, it is very difficult to control

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publicly traded firms in 2001 that built residential homes (Bashford 2004).

the arrival of subcontractors to the construction site so that it matches the arrival of needed materials, the work is conducted in the proper order, and when weather allows (Tatum 1986; Klozenbucher 2004).

Even the largest builders are too small to have either a buyer's monopoly over labor and input or a seller's monopoly over homebuyers, nor do the largest builders together have even close to an oligopoly. In 2002, the combined sales of top-ten builders controlled only 24% of the top 50 U.S. housing markets (Builder Online 2004a). None of these firms controlled these markets. For example, the 2002 top builder, D.R. Horton, was only able to capture 10.75 percent of any of the local markets in which it built homes (Builder Online 2004b). An average builder will be doing well if it controlled 4% or 5% of their local market (Builder Online 2004d).

However, many of the largest production builders have their own staff to appraisal, mortgage bankers to lend money, and professional realtors to market and sell new residential construction.[62] Smaller builders usually do not have their own in-house capabilities, and they instead do business with realtors and mortgage bankers who are independent businesses. Appraisers usually work directly for banks.

Specifically, there are three general ways that residential construction firms can use or not use realtors to sell their homes. *First*, there is the use of independent realtors, which tend to be used by smaller builders. It appears that most residential builders who sell on the speculative market do rely on independent real-estate firms for marketing and selling[63]. These independent real-estate firms provide a range of services to builders such as conducting market studies, planning advertising campaigns, furnishing the model homes, and, of course, the sale of new homes. Also, they may help plan new communities, assist with land acquisition, and keep builders informed about their competition (Amoruso 1998). However, even when builders use independents for these activities, they usually have in-house sales staff that coordinates activities with realtors (Amoruso 1999).

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[62] Conversations with industry participants and a scan of the web pages of some of the largest production builders suggest that this is common among the largest production builders.
[63] Personal communication with Bob Marvel, a realtor from Bob Marvel & Associates, Seattle WA, during Summer of 2003.

Because most builders sell a small number of homes to an small market of local buyers, it is not practical to develop in-house sales expertise and sophisticated marketing techniques and mass advertising. It is usually more practical for builders to allow independent realtors to hire and train staff and to bear the risks and hassles of staffing. Most independent realtors seem to do a satisfactory job of selling housing in local markets through their extensive sales networks and multiple listing services. Thus, most builders do not have a dire need to acquire their own sales staff, which is very different from many early manufacturers who had little choice but to develop their own sales staff and distribution networks.

There is a *second* way through which builders sell their completed homes. The larger production builders often employ their own in-house, real-estate professionals. The in-house agents engage in many of the activities that independents do, and they “are expected to know just about everything . . . about the land, construction materials, neighborhood, and the builder he represents” (Amoruso 1998). Of course, this arrangement allows the builder to control most aspects of the sales process.

Third, some building firms do not hire realtors market and sell their products, and insist on doing it themselves (Amoruso 1999). Some of these builders are probably small design-build firms that construct homes on a contract with the buyer, and realtors are not needed.

The use of in-house real-estate professionals appears to give builders more control over the selling of their homes, the level of commitment of real estate agents to them, and the skills and knowledge that agents possess—things that can be important when selling homes with new building technology. Being able to understand the benefits of any new technology that is incorporated into a new house is important to selling that house. In-house realtors are most likely to be able to do this. Independent realtors are often disconnected from the manufacturers of new technologies and their use in the building process (National Association Home Builders Research Center 2001b). The use of independent real estate marketing firms can be problematic because these builders have less control over their labor supply. Independent real-estate firms have been known to move real estate professionals ”from builder to builder” (Amoruso 1998) making it difficult for builders to assemble a full team of knowledgeable professionals to both make and sell homes with new residential housing technology.

There are other relevant organizations that, by definition, lie outside of the direct managerial control of residential construction firms. These include local code enforcement offices and other government administrative, legal, and regulatory bodies. There are also R&D organizations, but there will be an entire section devoted to these.

Just because an organization, such as a regulatory agency, realtor, or mortgage banker, is outside of a builder's direct managerial control, it does not mean that the builder cannot exert significant influence over it, or that there are not controls over the organization's activities. It has been stated that builders and developers exert a great deal of control over the regulatory activities of local governments (Trowbridge and Upton 2000). Builders and developers have a strong vested interest in the actions that government takes on growth planning, highway and road construction, annexations, zoning, environmental and health regulations for housing, and building codes. The firms of most builders and developers are too small to employ their own lobbyists and policy analysts, and tend to use the more informal means of actively participating in local elections, sitting on local planning and zoning commissions, and promoting a pro-growth ideology to governments that want to expand their tax base. On the other hand, the state and national building associations and specialty trade associations often have these abilities, and are very influential with local, state, and national government (Brix and Davis 2004; Nouraee 2003; National Association of Home Builders 2005a).

Also, even without direct control over realtors and bankers, my field research suggests that builders command a fair amount of clout in their professional relationships with realtors and bankers. This is because they have what each of the other two need access—homes to sell and buyers to finance. Realtors and bankers are always trying to network with builders so they can expand their customer base.

For gaining *information* about many parts of the system, most residential construction firms are too small to likely have their own organizational capacities to collect, process, and analyze information, nor the financial resources to contract for the collection of it. It appears that they are reliant on external organizations for collecting, maintaining, analyzing, and providing information about new technology, competitors, market demand, et cetera. This is another way that the industry is organizationally fragmented. External organizational sources of information include code inspectors, government agencies, and trade associations. However, these are often of limited usefulness.

Government agencies and trade associations collect general information on the market-place, firms within the residential housing industry, and other aspects of the industry. Some of the agencies are the U.S. Census Bureau, which conducts user, economic, and other surveys of the industry. Also, the Office of Energy Efficiency and Renewable Energy (in the U.S. Department of Energy) and the Partnership for Advancing Technology in Housing (located in the U.S. Department of Housing and Urban Development) maintain databases on energy efficient technologies. The best-known industry association is the National Home Builders Association that collects, maintains, and analyzes information about market demand, economic projections, building codes and other regulations. However, much of the information that is made available by these agencies and trade associations is often only on the national, and not on the building activities and real estate market at the local level. Also, it tends to be rather generic and often does not pertain to the needs of a builder, and may be of limited use for successful system building.

Codes inspections are a cheap substitute for rigorous in-house quality control programs to monitor the quality of completed homes. Residential construction firms are unusual in that it is one of the few industries that makes and sells complex technological products that does not have their own well-developed quality control capabilities. Most manufacturing firms have their own in-house, well-developed, organizational routines for quality control including technical standards and tests to monitor products at various stages of production.

Code inspections in many parts of the country do a poor job of catching many types of defects in residential buildings, particularly relating to energy efficiency, due to budget constraints and other reasons (Tracey 2003; City of Fort Collins 2002; Residential Energy Services Network 2001). Historically, codes have been a rather crude instrument to monitor the quality of new construction. Most codes are prescriptive. This means that a code specifies the types of building materials, techniques, and designs that can be used, but the actual performance of the building such as its energy efficiency, durability, and fire proof characteristics are not measured. Also, there is no way for code officials to gain information about the 70% of the home that is hidden inside of walls, foundations, floor, and roofing systems.

Codes are also an awkward means of quality control for new technology in part because codes tend to delay the introduction of new technology into the market and usually result in additional hassles for innovators. Due to a lack of coordination between R&D labs, government, and others there is a lag of at least three years to often considerably longer between the basic technological innovation and that innovation being recognized in codes (Duke 1988; Ventre 1973; Ehrenkrantz Group 1979). Also, the reliance on codes creates a patchwork of different standards in the national market place, and code officials often do not have expertise to rule on new technologies, which forces the builder to prove compliance (Slaughter 1991).

Another limitation is with builders themselves, particularly smaller firms. Many builders do not appear to have the capabilities to use of the information that is publicly available. What the firm must have is a set of human resources, routines, and organizational structures to regularly access the available information, process it into a form that is useful, and then incorporate it into its decision-making process. Without these structures, only a small amount of the available information is likely to be utilized.

The capacity to *centrally coordinate* the parts of its relevant sociotechnical system is crucial to engage in successful system building. However, as discussed in Chapter 2, the capacities for control and information are prerequisites to any meaningful capacity for coordination. For this reason alone, it is doubtful that most residential construction firms have much of a capacity to coordinate very many of the important parts of their relevant sociotechnical system.

Unfortunately, no data was found to directly assess the extent to which firms in the residential construction industry have a capacity for *strategic planning*. However, the small-business, organizational models of most builders and their tendency to lack professional management suggest that any capacities they have are probably limited.

Research and Development Capabilities in New Construction

Unfortunately, there has been very little scholarly research on the organization of R&D within the residential housing industry. However, there have been studies on other segments of the construction industry and on the industry as a whole.[64] While we should use caution in drawing conclusions specifically about residential R&D from theses studies, there are two reasons why these likely have some utility for our purposes. *First*, residential construction accounts for one-half or more of the construction industry, and therefore it has a substantial influence on industry-wide statistics.[65] *Second*, there are similarities in the construction process among the segments of the industry. The basic historical model that most of these firms share has been a small firm operating as general contractors that contract out for the assembly of prefabricated components, parts, and materials into buildings and other structures that are highly customized relative to the products of other industries.

How much R&D is there in the U.S. residential construction industry? It appears that there has not been very much formal R&D. The invention and innovation that does occur seems to almost exclusively be conducted in an *ad hoc* fashion by contractors, subcontractors, and design staff during the course of actually construction process, not by professional R&D staff in well equipped labs.

One measure is money spent on R&D. However, separate numbers are not available for residential R&D, only aggregate numbers for the industry as whole. The Committee on Construction Productivity believed that only a few builders were large enough to have R&D capabilities and were mostly focused on product evaluation—not systematic invention or innovation (Building Research Board 1986). Likewise, the National Science Foundation, which collects data on R&D money in each industry, did not bother with a category for construction R&D until 1999 because so little money was spent on it, and it

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[64] The construction industry includes residential construction but also commercial construction, transportation construction, marine construction, construction of manufacturing facilities, and other types of specialty construction.

[65] The residential construction counts for a majority of total dollar value of work done in the total construction industry, and an even larger majority of the number of general contractors. In 2003 residential construction accounted for 54% of the total construction dollar value (calculated using data from the U.S. Census Bureau 2004b), and in 1997 it accounted for about 78% of the firms that operated as general contractors within the construction industry (calculated using data from the U.S. Census Bureau 2004c).

still does not have a separate category for residential construction R&D.[66] Also, historically, there has been very little mention of residential construction R&D in the scholarly or trade literature. It is highly probable that there is even less R&D conducted for and by residential construction firms than the industry as a whole.

Also, there appears to be considerably less money spent on R&D by the U.S. construction industry than by most other U.S. industries[67] and by many other countries.[68] When firms in most other US industries were developing their own R&D capabilities in the 1920s, 30s, 40s, and 50s, construction firms showed little or no interest in conducting their own R&D. There was, however, more interest in construction R&D after WWII, but it was not by builders. Instead it was by the manufacturers of construction inputs, universities, federal agencies,[69] and non-profits that were all located on the periphery on the industry. None of the organizations actually engaged in construction (Building Research Board 1988; 1992).

Contractors, engineers, and architects spent only about $54 million on construction R&D in 1984—a very meager 0.04% of their sales. The amount of money from universities and private foundations to fund construction R&D was judged by the Committee on Construction Productivity to be approximately the same amount or less. However, other entities on the periphery of the construction industry have spent considerably more. The federal government has funded a significant amount of construction R&D

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[66] This information was from a personal communication with Raymond Wolfe, Division of Science Resources Statistics, National Science Foundation, Thursday, November 13, 2003. The National Science Foundation is one of the few sources of data on the money spent on R&D in U.S. industries. Also, none of the top 500 firms in 1997 for R&D as measured by total R&D expenditures were in the construction industry based on a survey of companies with 15 or more employees by the National Science Foundation (1999).

[67] The household appliance industry spends 1.4% of their total sales on R&D, automobiles spent 1.7%, and textiles spent 0.8% as an industry (Building Research Board 1986; 1988). However, high tech industries will spend many times that. Firms in electronics or medical supplies and equipment will spend between 5% and 11% of domestic sales on R&D (Shepherd and Payson 1999).

[68] In the early 80s, despite is smaller economy Japan spent two or three times as much on construction R&D as the United States. Also, Sweden and Demark spent about five times that of the United States (Sebestyen 1983). "With few notable exceptions, particularly in the building materials and equipment sector . . . investment in R&D is low by international standards" (Seaden 1996, 106).

[69] Some government agencies with construction R&D capabilities are the Department of Energy; U.S. Army Corps of Engineers; Naval Facilities Engineering Command; U.S. Postal Service; National Institute of Standards and Technology; State of Maryland; and Montgomery County, Maryland. Some are geared heavily toward basic invention, such as the US Department of Energy. Others such as Montgomery County focus almost entirely on

although the lack of accurate figures has frustrated efforts to determine exactly how much. It appears to have been less than $200 million in 1984. The largest amount of money spent on construction R&D has probably been by manufacturers of construction materials, supplies, components, and equipment at about $838 million in 1984, and all other economic sectors spent approximately $111 million on construction related R&D in that year. This came to a total of no more than $1,233 million spent on construction R&D, or 0.4% of total construction sales in 1984 which is far below most other technology intensive industries (Building Research Board 1986; 1988).

It should be remembered that these numbers are for the construction industry overall, and probably overestimate of the amount of R&D in residential construction by a considerable amount. Based on all the sources cited for this topic, most construction R&D appears to be on non-residential construction.

Innovation in Construction Firms

However, the small amount of money spent on R&D is not the only problem for residential construction. The root of the problem is that the industry's R&D staff is usually not located in the same organizations that actually engage in the construction, marketing, and sales of new residential dwellings. This lack of integration is a serious impediment to the transfer of new technology from the R&D labs to the building process (Build Research Board 1992; Hutcheson et al. 1996; Johnson 1993). Likewise, the overall fragmentation of the construction industry makes it difficult for the R&D staff to control and coordinate the introduction of new technology (Office of Technology Assessment 1986c). Of course, R&D labs do sometimes cooperate with builders, architects, and subcontractors, and manufacturers of construction inputs do sometimes cooperate with each other on the development of new technology, but it is not the same as builders having their own well developed R&D capabilities.

Technology cannot be integrated into a builder's organization by an outside R&D lab. It is something that a residential construction firm must do for itself. There seems to be a popular conception that R&D labs are primarily for generating new inventions, but most are not used for this purpose. Most R&D labs

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innovation within their own remodeling, construction, and engineering activities (Building Research Board 1992).

that successfully introduce new products focus on innovation—taking inventions from outside organizations and integrating them into their own organization’s production and marketing activities. In other words, innovation is fundamentally a process of organizational learning. An external R&D unit cannot learn for a builder any more than a teacher can learn for a student. Likewise, much of the knowledge about how to use inventions is tacit knowledge that cannot be written down but instead must be learned by participating in the R&D process. Also, firms have their own tacit knowledge that is crucial to the innovative process. External R&D labs don’t have the right kind of information about the fit between an invention and a builder’s organization, the perspective to assess this fit, and the ability to control and coordinate the relevant parts of the builder’s organization and larger system to improve this fit (see Slaughter 1991 for similar comments).

There is some direct and indirect empirical support for these statements. As already mention, most construction firms do not have anything even close to their own well-funded, formal R&D unit. In 1984, roughly two-thirds of the construction R&D money was spent in R&D labs owned by manufacturers of construction inputs, and another two-ninths was spent at university construction labs. The remaining one-ninth was spent at an assortment of federal labs, non-profits, and also perhaps a few private research facilities that are owned by construction companies (Building Research Board 1988; 1992).

Also, university and federal labs have historically given little consideration to how their inventions might be used and if they are marketable. Research activities at federal labs and universities are more of an exercise at “trying out new ideas rather than developing . . . profitable new products” as a private company would. Likewise, there is often little testing or prototyping of inventions (Building Research Board 1992, 28).

Even when external R&D labs do give consideration to these things, they often do not have an effective pathway to transfer inventions to builders. Nearly one half of government R&D labs had no structured program to transfer technology to users (Scott et al. 1991) despite a congressional mandate to do so. Those that did attempt to comply usually did not do so adequately (Building Research Board 1992). Even when federal and university labs are committed to technology transfer, it is still a fundamentally difficult process to transfer inventions to the decentralized residential housing industry with its tens of thousands of small and medium sized organizations. Because these government labs do not even have a market relationship with builders, the only options available to engage in technology transfer have historically been limited to technical reports, workshops, demonstrations, or locating those rare builders that are willing to enter into a joint venture for commercialization (Building Research Board 1992). Formal R&D laboratories that are managed by the federal government, universities, and non-profits appeared to have had little or no discernable direct impact on technological change during much of this time period (see Slaughter 1991) despite millions of dollars per year that have often been spent on R&D in these labs.

The manufacturers of construction inputs seem to do better. They have established market relationships to transfer technology from their R&D labs to builders and to follow up with customer support, service, and repair as appropriate. Some authors have noted that innovation is more likely to occur when there are close ties between the source of an invention and the intended users of it (Building Research Board 1992). In fact, of the 117 innovations in the residential construction industry that were commercialized from 1945 to 1990 that were identified, the vast majority were provided by manufacturers as opposed to builders and subcontractors on the job site. The innovations on the job site tended to be process-innovations, which were new ways of using and combining materials, supplies, and equipment (Slaughter 1991). Despite the usefulness of the market relationship that the manufacturers of construction inputs have with builders, it does not allow for as much integration as managerial hierarchies. Indeed, more control and coordination would be useful. Some authors have noted that builders are often not very interested in, or do not know what to do with, new technologies that come from the R&D labs of input manufacturers (Building Research Board 1986; Hutcheson et al. 1996). It seems to be difficult for manufacturers to integrate their R&D with the construction process through market relationships.

The fundamental problem appears to be that builders do not have their own R&D capabilities with an associated set of routines to keep aware of new inventions, evaluate the fit of these inventions with their organization and larger system, and reshape both the invention and their organizations and larger system to improve this fit. A similar assessment was made by the Building Research Board (1988; 1992) and is also supported by comments from Nam and Tatum (1989) and others who noted that few, if any, residential construction firms have clearly defined roles for employees to participate in research and development. Nam and Tatum also suggested that top management in residential construction firms usually does not place an emphasis on bringing in new inventions and coordinating their introduction to their firms. More generally, most builders seem to lack the prerequisites to be successful at R&D. They have few professional staff, and often do not even employ their own engineering or architectural staff (Koebel et al. 2004). As already discussed, most often they do not have the organizational capabilities to purchase their construction inputs directly from manufacturers, but they must rely on the inventories of local building supply stores and the store's distributors. They do not have the capacity to conduct or perhaps even commission market studies that are needed to collect information about the fit between inventions and the larger system. Likewise, they lack management structures to control and coordinate enough of their industry to introduce new systematic innovations into their relevant sociotechnical system.

Much of the invention and innovation within the residential housing industry is conducted through case-by-case problem solving—the *ad hoc* seeking out of new technology to address the needs of specific projects. With little coordination from top management, it appears to be construction workers with no experience or training in R&D who end up evaluating new technology and integrating it with the organization and broader system, if this is done at all (Building Research board 1992; Slaughter 1991).

Also, innovation is often temporary for certain types of construction because of the difficulty of establishing new work routines. For example, marine construction firms will adopt new technologies to build one-of-a-kind structures, and then abandon these technologies after completion (Johnson 1993). Nam and Tatum (1989) concur that it can be difficult for a builder to keep the ability to use a new innovation from one project to the next. The likely reason is that laborers and subcontractors who are a firm's reservoir of tacit knowledge have a very high turnover rate and only work for a contractor for a job or two, as mentioned above.

However, builders' interest in R&D and their abilities to engage in these activities appears to be undergoing change. Through its Building America Program, the Department of Energy has facilitated a few, high profile, collaborative R&D efforts involving construction R&D labs, building science consultants, manufacturers of construction inputs, and some of the largest production builders in the country. Partnership for Advancing Technologies in Housing (PATH) at the Department of Housing and Urban Development is conducting a similar effort (Partnership for Advanced Housing Technology 2005). Both programs appear to be having some initial success, but evaluating these is beyond this study. Nevertheless, the above analysis suggests that the organizational structures of large production builders that are participating in these collaborative efforts are more suitable to conducting successful R&D or at least developing these R&D capabilities than other smaller construction firms.

Chapter 8: Existing Home Side of the Residential Housing Industry

Existing housing has a very significant, conservative influence on technological change in the residential housing system. This is because the volume of existing home sales is substantially larger than new home sales, and the durability of residential dwellings ensures that the technological choices made over 60 years ago are still part of the existing housing stock. However, technological change still does occur among existing housing. Organizationally, firms on the existing housing side of the industry appear to be even less able to control the pace and direction of technological change. Ownership and control of residential housing and the firms involved in real-estate transactions are even more fragmented, decentralized, and less likely to be professionally managed than for new construction.

The process of buying and selling existing residential homes is a part of the housing industry where technological choice is at the forefront, and is an opportunity for policy makers and participant-advocates of alternative technology to intervene at the "point of sale." EEMs are "point of sale" interventions, and HERS have important implications as well. At the time of sale, buyers weigh their technological options among different existing homes and the purchase of new homes. Also, both buyers and sellers will often make decisions to retrofit, repair, or maintain homes that are influenced by the real-estate market and larger housing industry. However, the process of buying and selling homes is extremely fragmented with dozens of different real estate professionals that each belong to different small, decentralized, highly specialized firms with few organizational capacities for system building.

Technological Change in the Existing Home Market

The technology in existing residential construction tends to lag behind the technology in new construction in terms of energy efficiency, durability, and modern amenities. Because the existing housing market is much larger than new construction, this tends to define the overall housing market in most localities. There were 82.1 million existing single-family homes in the United States in 2003 (U.S. Census Bureau 2004h), and 6.1 million were re-sold that year (National Association of Realtors 2004).

This compares to only 1.1 million new single-family units sold in 2003 (U.S. Census Bureau 2004k) and another few 100 thousand that were self-built (Rappaport and Cole 2000).

Another factor is the difficulty of retrofitting existing homes with many types of new technology (Suozzo et al. 1997, 5). Once a house is built, the basic structural and thermal characteristics of it are relatively fixed. Many of the most important technological choices have been made for all future owners, which has often been for 60 or more years.

Nevertheless, technological change does occur in existing housing (Heschong Mahone Group 2004), and there are many types of firms specializing in retrofitting, maintaining, and repairing. These firms include small handy-man business, larger firms that specialize in remodeling, HVAC contractors, appliance dealers, and also manufacturers of supplies, materials, and equipment for home repair. The types of technology that are most likely to change are shingles, floor coverings, paint, siding, appliances, HVAC systems and insulation. Also, many of the firms that participate in real-estate transactions help buyers assess the technology in residential homes and recommend changes. These organizations are of course appraisers, home inspectors, and to some extent realtors, attorneys, and even title agents.

Maintenance, repairs, and retrofitting/improvements accounted for $177 billion of sales (34%) in 2003 for single and multi-family dwellings out of $346 billion in total construction for single and multi-family dwellings. New construction accounted for the remaining 66%.[70] Approximately one-half of this work was conducted by homeowners, and the other one-half by contractors specializing in remodeling or a special trade (U.S. Census Bureau 2001). Of course, these dollar values do not say anything about the specific technology that was used, which is more difficult to assess.

The technological change that results from such activities appears to be conservative and with few systematic innovations. For example, recycling centers were one of the most popular options in kitchen remodeling jobs according to a membership survey. Although fluorescent lighting is not as popular as

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[70] There was approximately $177 billion of maintenance, repairs, and retrofits/improvements in 2003 for single and multi-family dwellings (U.S. Census Bureau, 2004e), and there was $346 billion dollars of newly constructed single and multifamily residential dwellings in 2003 (U.S. Census Bureau, 2004g).

recycling, it was included in over 10% of the kitchen and bathroom remodeling jobs (Sovereign Marketing Research 2001).[71]

Also, from the American Housing Survey we know that 4% created a room, and 11% remodeled a room, Also, door or windows were added or replaced in 12% of the housing units in 2001, insulation in 4%, carpeting in 12%, central air conditioning in 5%, heating equipment in 5%, water heater in 8%, roofing in 9%, and siding in 3% (U.S. Census Bureau 2001). This corresponds reasonably close to that reported by the National Association of the Remodeling Industry (NARI), approximately 41 million Americans undertook home improvements during 2000 and 2001. About one-third of these projects involved the replacement of either a structural element or a subsystem, and 1 million per year was in major renovations. Also, it is generally agreed that HVAC units fail and are replaced about every 15 years (FMI 2004). Most construction activities appear to involve autonomous innovation, such as new paints, coverings, and HVAC equipment that were likely adopted from the new construction side of the industry. As mentioned above, once a house is built, it is even more difficult to incorporate a systematic innovation into its structure.

There appears to be a few reasons why technological change among existing housing occurs slowly and apparently involves mostly autonomous innovations. One reason has been mentioned. This was the difficulty and expense of retrofitting existing homes, particularly with systematic technology. A second set of likely reasons is the lack of organizational capacities for system building of those who control the existing housing stock, and a third set is the lack of organizational capacities by firms that operate on the existing housing side of the industry.

The Organization of the Existing Housing Market

This section will explore the structures and capacities of construction and real-estate related firms on the existing housing side of the residential housing industry. However, there is even less available information on the organizational characteristics of existing housing than on new construction. Also,

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[71] The response rate of this survey was very low, and their sampling list was probably not representative of the

because there is no single type of organization that plays a central role in technological choice even, there is no easy way to organize the discussion. Firms that conduct maintenance, repairs, and retrofits are important, but so are homeowners, realtors, and mortgage bankers. However, homeowners almost completely lack organizational capacities for system building. Realtors are important in coordinating real-estate transactions, but they have limited capacities and are rather disinterested in technological change.

Ownership and Management of the Existing Housing Stock

The existing housing stock is mostly owned and controlled by homeowners and small businesses that may or may not manage their own properties. In 1993 this extremely decentralized ownership structure had 67 million owner-occupied units, and also 35 million renter-occupied units72 and 12 million vacant units (U.S. Census Bureau 2004f). A substantial majority of the single-family rental properties have been held by individual investors who own and self-manage a small number of units.[73] The number of units owned and the sophistication of the management of most multi-family rental units appears to have been greater, but they are still few in number and with relatively simple management structures compared to firms in most other industries.[74] Also, 98% of all rental management companies with employees had an office in a single locality (U.S. Bureau of the Census 2000a), and most owners of rental property usually own no more than one or two dwellings. This extremely decentralized, small-scale ownership and management structure has spread the control of the residential housing stock over 80 million or more decision-makers.

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population of homeowners. Therefore, the results should be cautiously interpreted.

[72] Approximately 70% of the 35 million renter-occupied units were multi-family units and the remaining 30% were single family units (U.S. Census Bureau 2004f).

[73] About 83% of single-family rental units were owned by individual investors. Approximately, 63% of single-family rental units were managed by individual investors had between one and nine units, and 77% were self-managed by the owner. These numbers were calculated from data by the U.S. Census Bureau (1998).

[74] About 47% of units were owned by individual investors. Approximately, 47% of multi-family rental units were owned by entities that owned between 2 and 49 units. Also, about 33% of multi-family rental units were managed by individuals; 34% was managed by one of the residents; and the remaining 33% was managed by another professional or business that specializes in property management. These numbers were calculated from data by the U.S. Census Bureau (1998).

It may seem strange to discuss households as organizational decision-making units that have or do not have capacities for system building. It is of course true that household units are organized around child rearing and other domestic activities, not the facilitation of systematic technical change. However, that is the key point. Although homeowners have ownership control over their homes, they usually have none of the other organization capacities for system building.

To most homeowners, a residential dwelling is a technological black box of which they have little understanding. If it is a technology that is located within the walls of their home, it is out of sight, out of mind. As Mullens and Hastak (2004) stated, they "care little about [technical] quality" except for "the cosmetic" aspects of it and the straight-forward technical services that residential construction technology can deliver (also see National Association of Home Builders Research Center 2001b). Likewise, many homeowners appear to lack the skills to gain information, make effective decisions, and coordinate the retrofitting of new technologies (see Stern 1986; Lutzenhiser 1993; Kempton and Montgomery 1982 for similar comments).

Energy efficiency is a case in point. Although homeowners say energy efficiency is important to them on survey questionnaires (Farhar 1994), it does not appear to be a salient value for homebuyers. Likewise, housing professionals consistently state that homebuyers rarely ask about the energy efficiency of a home.[75] Although many homeowners and buyers do seem to value energy efficiency in the abstract, energy consumption is a largely invisible part of their home.

Likewise, most homeowners have little practical experience directly with energy efficiency (Kempton and Montgomery 1982). Technological choices such as for new furnaces, hot water heaters, insulation, or a new home that have significant impacts on energy use are very infrequent. Thus, the gathering of information, weighing options, and coordinating the activities of housing professionals never has a chance of developing into a set of routines that can be used the next time that a similar decision must be made about purchasing energy technology.

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[75] Dozens of housing professionals were interviewed for the case study in chapter 8, and all them indicated that home seldom if ever mention energy efficiency on their own when choosing housing technology.

Of course, there are organizations within the industry that have many of the capabilities that home owners lack, and in theory they can help them maintain, repair, and retrofit their home with new technology. This includes advocates for alternative technologies and mainstream firms such as contractors, realtors, appraisers, home inspectors, mortgage originators, underwriters, secondary lenders, and also mortgage insurers; code enforcement agencies; and home insurance companies.

However, in many instances homeowners do not have the organizational capacities to successfully engage the help of these other specialist firms in the industry for maintaining, repairing, and retrofitting their home. In part because households are structures around domestic routines, they apparently lack the organizational routines to gather contact information about these firms and to coordinate activities among them. This seems to be particularly the case when the new technology involves highly systematic innovations (based on interviews with industry participants).

Firms Engaging in Maintenance, Repairs, and Retro-Fits

Although all the firms that conduct maintenance, repairs, and retrofits on residential housing are small by the standards of the rest of the economy, many of them are considerably larger than the traditional handyman. These firms include remodelers that mainly focus on existing construction and also firms that conduct work in HVAC, carpentry, roofing, flooring, plumbing, drywall, electrical, and other trades for both new and existing construction.

In 2003 the top-ten remodeling firms in the United States each had gross residential sales that were $60 million or more. The largest firm, Disaster Kleenup International, had a sales volume of over $405 million[76] and conducted over restoration 59,000 jobs on residential, commercial, and government buildings (Qualified Remodeler 2005).

In 2003 the top three remodeling firms specialized in restoration after disasters, which often involves large contracts and probably accounts for the size of these firms. Also, many of the top twenty remodeling firms did a substantial amount of work for government and commercial clients, which also

[76] The numbers and data from Qualified Remodeler (2005).

involve larger contacts than individual residential clients. However, other top firms have managed to grow by focusing on traditional residential remodeling, such as Champion Window & Patio Room, U.S. Home Systems, Handyman Connection, and Thermoview Industries. Sales of these four firms ranged from $70,080,000 to $242,779,711. Firms either conducted full-service remodeling, or specialized in windows, siding, awnings, doors, kitchens, and or bathrooms. Also, some engaged in design-build remodeling (Qualified Remodeler 2005). Also, many of these remodeling firms were diversified into additional products and services. The means of growth and financing system-building activities have varied by firm. Two of the top-ten firms, U.S. Home Systems and Thermoview Industries, were publicly traded companies giving them an important source of investment capital. Patio Enclosures was moving to an employee owned model. Most of the top-ten firms and some of the smaller firms also operated under the franchise, agent, and/or dealership model of business and ranged between dozen to a few hundred local partners (Qualified Remodeler 2005). Franchises, agents, and/or dealerships allow for very fast expansion—a couple of companies reach the top ten in ten years—but it is not very useful to concentrate investment capital.[77] Overall, remodeling firms are smaller than residential builders, and the top 100 remodelers as a group have less control over the remodeling market than the top builders of new construction. As noted, the largest builder D.R. Horton had over $9 billion of sales in 2003 (Builder Online 2005), which is more than the top one hundred remodeling firms that had a combined sales volume of about $2.271 billion in residential, commercial, and government sales (Qualified Remodeler 2005). Furthermore, these top 100 remodelers hold about only 1% of the residential market for remodeling contracts.[78]

About half of the top-ten firms were vertically integrated downstream into manufacturing of components (such as windows, doors, patio rooms, and cabinets) and upstream into direct sales to customers through retail outlets that were either own by the firm, dealership, or agents. Of course they also installed these and other components. At least two of them had a division or a subsidiary that

[77] Data from (Qualified Remodeler 2005) was supplemented with a scan of the firm's web pages.
[78] Numbers were calculated from data provided by Qualified Remodeler (2005).

financed home improvements and repairs. Of the top thirty-three remodeling companies, ten were diversified into larger regional or national markets**.** [79]

This integration—especially of manufacturing, design, sales, and installation—appears to have provided an important set of organizational capacities to introduce new technologies for remodeling. Many of these such as patio enclosures, seamless gutters, and eaves cannot easily be sold through traditional retail outlets or left up to independent contractors to install because of specialized training or equipment. Firms such as Patio Enclosures have been able to develop their technology of enclosures for patios, market it directly to consumers, design, and install about $60 million worth of enclosures per year. Also, some of the other remodeling firms also offer financing to their customers.[80]

There were also over 500 somewhat smaller remodelers, usually local firms that each had sales of $1 million or more in 2003, and many of them completed up to a thousand contracts. These firms were more likely to be full-service remodelers and engage in design-build remodeling. Some of them also had a franchise and/or dealership structure (Qualified Remodeler 2005). Of course, the industry has tens of thousands of other even smaller firms that in total hold a large portion of the market for remodeling.

As mentioned, a large majority of HVAC, carpentry, roofing, plumbing, drywall, electrical, and other specialty trades were not part of the data from which numbers about the remodeling were obtained. These and other specialty firms are also important to maintenance, repairs, and retrofits/improvements. As noted in the chapter on new construction, these firms are also very decentralized.[81]

If this sounds similar to the discussion in Chapter 6 about lack of organizational capacities on the new housing side of the industry, it is in part because many of the firms that do maintenance, repairs, and retrofitting are also contractors that build new housing or are subcontracted to do work. Just as on the new housing side, there is a large amount of fragmentation on the existing housing side into narrow specialties for design, financing, carpentry, roofing, and electrical work, and the installation of insulation

[79] Numbers were calculated from data provided by Qualified Remodeler (2005).
[80] This information was obtained from a scan of web pages of many of the top firms.
[81] The data sets are different for remodeling firms and for builders and specialty trade contractors.

and HVAC equipment. Just as on the new housing side, this fragmentation can present a major challenge to introducing systematic innovations (see Suozzo et al. 1997, 5 for similar comments).

Although no one has ever accused any of these firms of efficiency, they appear to have developed ways to cope with the challenges of coordination just as builders have done so. This appears to have been done through an elaborate set of decentralized, formal and informal network relations, traditions, and industry standards that guide activities and decision-making within the industry (of which some of these will be described in the next chapter). These network relations that guide technological choice are often heavily steeped tradition.

The Influences upon Technological Choice of Buying and Selling Existing Homes

The processes of buying and selling existing residential dwellings appear to have an influence on technological change. It is common for prospective sellers of residential homes to improve their properties and make these more attractive to buyers with new paint, landscaping, insulation, HVAC, and roofing systems. Furthermore, there are normative pressures to ensure that homes are up to the standards of the community, and government officials, realtors, bankers, appraisers, and home inspectors play an important role in setting standards, assessing deficiencies, and recommending retrofits, repairs, and maintenance.

Discussed below, it appears both buyers and mortgage bankers have a strong vested interest in making sure that residential dwellings meet community standards. As previously commented, residential dwellings are one of the most expensive, technically complex, products that most people will ever purchase and that can also have implications for their personal health and safety. Real-estate transactions are also time-consuming, difficult, and risky, and it appears to be for that reason that homebuyers are usually very willing to pay professionals such as home inspectors, appraisers, attorneys, code enforcement agencies, and radon and pest control experts for technical, legal, and financial advice. Also, mortgage lenders have a vested interest in making sure that existing homes meet these standards, because if homes do not then they can incur liability if they must foreclose.

Because real-estate transactions focus people's attention on technological choice, energy policy professionals have taken an interest in the "point of sale" to facilitate technological change toward policy goals such as energy efficiency. This is the approach taken by HERS and EEM advocates that is discussed in the next two chapters. According the Heschong Mahone Group (2004), a real estate sale

> in many cases, provides a good trigger event to install certain basic equipment such as demand responsive lighting controls or appliance tune-up and can result in a significant amount of energy savings (p. 10).

However, the bankers, appraisers, and inspectors who exert normative pressures to upgrade homes to community standards do not appear to be a vanguard of technological change. Instead, these seem to be the rear guard that functions to bring the bottom up, and because of this technological change in the existing home side of the industry is typically quite conservative. Furthermore, these dominant organizations appear to sometimes stifle more radical technological change, which will be touched upon below and discussed in great detail in the next to two chapters.

To make effective "point of sale" interventions, we need to understand the motivations of the diverse group of housing professionals involved in real-estate transactions, their roles in relation to one another, and their organizational capacities for both maintaining existing systems arrangements and building new ones. It is important to understand just how extremely decentralized, fragmented, and compartmentalized these firms are into various specialties that tend to be guided by existing assumptions and parochial interests. There is coordination in the industry, but much of it is through decentralized structures such as norms, standards, traditions, contracts, regulations, and codes of ethics. These decentralized structures have been quite effective at providing stability and ensuring that real-estate transactions are completed with a reasonable amount of speed and efficiency. However, they do not seem to be very effective at coordinating the introduction of new inventions, and instead seem to be inherently conservative and resistant of change.

The rest of this chapter is a description of the process of buying and selling residential dwellings, and some of the major organizations, norms, standards, traditions, and regulations, and most importantly how these appear to influence technological choice. Where information is available, I also discuss the capacities of the involved organizations. The process, organizations, and decentralized structures do vary somewhat with different jurisdictions, prerogatives of the buyers and sellers, and characteristics of the property being bought and sold.

Organizations, Institutions, and the Process of Real-Estate Transactions

Too much emphasis cannot be placed on the complexity, fragmentation, and decentralization of the process of buying and selling existing homes and of the number of organizations involved. For almost any other item that is bought and sold, a buyer can walk up to a seller and then walk away with legal possession of the item after they pay for it. This is not the case with residential property. It usually takes a few months to a few years to find, negotiate, purchase, and gain legal possession of a property. This complex, time-consuming process commonly involves 70 or more individual real-estate professionals in over a dozen different organizations that navigate homebuyers and sellers through maze of codes and regulations; contracts and other network relationships; and financial, legal, and health and safety risks, as shown in Table 8-1.

Realtors play a central role in real-estate transactions beyond that of just listing and showing homes. Brokers and their agents coordinate the activities of various industry participants, assist both buyers and sellers in a variety of ways, and act as trouble shooters until everything is finalized (Farhar et al., 1996; U.S. Bureau of Labor Statistics 2004). The process is fairly easy for the seller. Some sellers will handle these transactions on their own, but once they decide that they want to sell the first thing that most of them do is find a realtor to list their home on a multiple listing service (MLS). They then leave most of the details of marketing and selling their home to the real-estate professionals. However, for the buyer and their realtor, the process is more difficult. Each time the realtor locates a house in which their client is interested, the realtor starts to facilitate a process of showing the dwellings which often leads to making

Table 8-1. A typical process for buying and selling residential real estate: The information within this table is from Boulder Real Estate Services (n.d.) unless otherwise noted.

Initial planning

The very beginning: time indefinite

1. The homeowner conducts research about home buying and available real estate professionals.
2. Initial Counseling session for homebuyers that are often given by real estate or government agencies.
3. Home buyers select a realtor and sign a contract with him or her.
4. The realtor will often review initial market matches to buyer's wants and needs.

Becoming pre-qualified or pre-approved: 1-3 hrs.

5. Buyers choose a mortgage lender.
6. Buyers become either pre-qualified or pre-approved for a mortgage to demonstrate to sellers that they can obtain the financing. This often needs to occur before a seller shows a home.
   - *Pre-qualification* with a lender gives an approximation of what a buyer can borrow, the loan programs for which they qualify, down payment, and monthly mortgage payment. The necessary information about assets is usually given over the phone.
   - *Pre-approval* "goes one step further" and involves a "complete *verification* of asset, credit and employment information," and allows for the approval of full credit. The buyer will know exactly the maximum loan amount and what loan programs for which he or she has been approved. This process can be occurring while the buyer is looking for your new home. Once "pre-approval is obtained, it normally shortens the time from contract to closing."

Viewing properties: time indefinite

7. The buyer's realtor conducts daily searches of new listings for a property match.
8. Whenever matches are found, the buyer is contacted to determine their interest in it.
9. Upon the buyer's request, the realtor schedules a showing of the property.
10. The buyer visits the property.

Writing offers: about 1-2 hours to complete each one

11. The buyer's realtor obtains the assessor's record, comparable sale data and MLS history for property.
12. The realtor or an attorney drafts an offer which includes information about the "price, address of the property, personal property," amount of the mortgage that is being "attempting to obtain, date by which you hope to obtain it, property inspection contingencies, and date of closing" (Yamin 2004).
13. The buyer places earnest money in an escrow account with a title and escrow firm.
14. The realtor reviews the offer with the buyer and obtains buyer's signature.
15. The offer is delivered or faxed to the seller via their listing agent.

Negotiating offers: *the time is variable, but often is 1-5 days if both parties are serious.*

16. Listing agent reviews offer with seller and recommends a response. Response usually must be made within 24 hours of receipt. If original offer is not acceptable, the seller's listing agent prepares a counter offer, seller signs and counter is delivered to the buyer.
17. Buyer and his/her realtor reviews counter offer and either counters the counter, rejects the counter, or signs the counter (several rounds of this may occur). The details that are negotiated can include
   - the sale price
   - technical problems with the dwelling and property
   - exist clauses
   - closing dates

18. Once an offer is accepted and signed by both parties, the property is “under contract,” which has specific legal meanings. It is “the basis for both parties going forward in good faith based upon a meeting of the minds” and specifically includes conditions that both the buyer and the seller need to address before the contract can be closed (Yamin 2004). These contracts have exit clauses for the buyer and seller that can be used if conditions are not met or certain events occur.

Steps that must be taken before the contract with the bank can close:

The time it takes to reach a fully executable contract varies, and depends on if the buyer was pre-qualified or pre-approved. It typically ranges from 1 day to 5 days.

Odds-and-ends

19. Buyer makes formal loan application and pays for credit report and appraisal.
20. Buyer provides a receipt of payment for home insurance and any other documentation and information that is needed by the bank.
21. The lender verifies the information and documentation.
22. Buyer "locks-in" interest rate and points.

Appraisal

23. Appraisal is scheduled by lender.
24. Appraiser assesses the value of the property.
25. If appraised value is below sale price, the parties to the “offer to purchase” pursue a way to close the gap between available financing and the sale price, closing costs, and fees. There are several options:
    - The seller and buyer can re-negotiate the sale price.
    - The buyer can put more money down.
    - Pursue other options, such as an Energy Mortgage that can stretch borrowing ratios.

Closing the contract with the bank

26. The borrower and the lender verify that conditions have been met to enter a contract for financing, and, if satisfactory, sign up to forty documents including the actual mortgage, “affidavits, truth-in-lending statements, estimate of closing costs, and the escrow statement letter that outlines how much will be paid in to the real estate tax and insurance escrows” (Glink 2004a; also see Yamin 2004).

Steps before the contract with the seller can be closed

The buyer’s realtor and the listing agent try to ensure that all parties meet all the conditions in the “offer to purchase” (U.S. Bureau of Labor Statistics 2004). This usually takes 1-6 weeks.

Assorted tasks performed by the listing agent.

27. At seller’s option, the MLS is informed that property is "under contract taking back-ups.”
28. Office closing file is set up.
39. Calendar outlining dates according to the contract is prepared and sent to buyer.
30. Sends to buyer and their realtor for review and signature the seller’s property disclosure form.
31. Sends to buyer and their realtor for review and signature the lead-based paint disclosure form.
32. Sends to buyer and their realtor for review and signature the land & improvement size notice form.

Title Search

33. Title search and commitment is ordered.
34. Signed “offer to purchase” and closing instructions are delivered to the title company (Listing agents/sellers usually select title company but buyer has the right to select).
35. Title commitment is received, reviewed by the listing agent and filed.
36. Title commitment is delivered to and reviewed with Buyer, and problems are addressed.
37. Title commitment is delivered to seller/listing agent for their review.

38. Settlement statement is received from Title Company and reviewed with buyer.
49. Improvement location certificate completed by surveyor.
40. Title insurance is obtained.
41. Any corrections necessary to the settlement statement are made prior to closing.

Inspection

42. Professional inspection(s) is scheduled by the buyer, agent or the listing agent. "There are many reputable building inspectors, radon specialists, termite inspectors and others which your agent can refer you to" and potentially others parts of the home that could require a specialist such as the septic system, wells, and underground storage tanks (Yamin 2004; Bureau of Labor Statistics 2004).
43. Professional inspection(s) is completed.
44. Buyer notifies seller of any significant problems based on the inspection.
45. Through their respective agents, seller and buyer negotiate a resolution to problems based on the inspection. This "opens" the contract and may result in a failure to close on it.
46. The seller often agrees to make repairs or retrofits to bring a house up to community standards. Contracts will often not close until problems are corrected (Bureau of Labor Statistics 2004).

Odds and ends

47. The buyer's agent prepares and sends due diligence letter to listing agent, cc: buyer.
48. The listing agents send the buyer's lender a weekly update.
49. The lender informs the seller and listing agent about the buyer's loan progress.
50. The buyer will sometimes order hazard insurance on the home they are about to purchase.

Final steps

51. Scheduled the date, time, and location of the closing with the title/escrow company, attorney, seller, buyer, and selling agent. Obtained notarized powers-of-attorney for those who cannot attend.
52. The "walk-through" inspection is scheduled (usually within 24 hours of closing).
53. Seller moves out of property prior to date and time of closing (unless contract states otherwise), leaving property in "broom clean" condition unless contract requires professional cleaning.
54. Buyer completes final walk-through inspection and notifies seller of any unacceptable conditions. This may include any repairs that resulted from the professional inspection(s) have not been adequately completed (Yamin 2004; Boulder Real Estate Services, Ltd. n.d.).
55. If an escrow account is being used, the buyer transfers the agreed upon price plus, closing costs, and fees to into the escrow account that is being managed by the real estate attorney, title company, or occasionally the realtor that is conducting the closing.

Closing on the final contract between buyer and seller: *usually about 1 hr.*

56. Before signing, the attorney will check "documents that may have been required in the contract, including paid water [fuel, and electricity] bills, certificates of compliance with laws pertaining to smoke-detection equipment, lead paint, termite or radon inspection" varying by jurisdiction. Documents are then signed, dated, and notarized.
57. The title company disbursement the funds. It takes the money from the buyer, and cut checks to the seller, the lender, the brokers, the title company, attorneys, and others (Glink 2004a).
58. The buyer receives the warranty, deed, and keys.

The buyer moves in

offers for it that quickly starts to involve bankers, listing agents, sellers, appraisers, home inspectors, government regulators, contractors, title agents, attorneys, et cetera. If an offer is not accepted, frequently the process is started over again (see Table 8-1).

It was mentioned that as a group of businesses, real-estate sales firms are very decentralized and fragmented. In 2002 there were 590 thousand of these firms[82] (U.S. Census Bureau 2004l) and most were small offices and many were staffed by only one-person businesses. “Many realtors worked part time, combining their real estate activities with other careers. Almost 6 out of 10 real-estate agents and brokers were self-employed” (U.S. Bureau of Labor Statistics 2004). Over 97% of the real estate sales firms operated an office in only one physical location (U.S. Census Bureau 2000).

There have been an increasing number of national and regional real-estate sales firms. In 1993, there were 365 firms with over $10 million in revenue, and most of these firms had offices in 3 or more locations. The largest twelve of them averaged about 100 locations and revenues of over $100 million[83] (U.S. Census Bureau 2000). However, it does not appear to have added much central coordination and control to the industry. Most large firms are themselves very decentralized and appear to have little influence over what happens in the local offices because many of them operate as franchises and through broker-agent models. Many of the national or regional real estate firms are franchises that allow local brokers to use their name for marketing in exchange for a fee. “Although [local] franchised brokers often receive help in training sales staff and running their offices, they bear the ultimate responsibility for the success or failure of their firms” (Bureau of Labor Statistics 2004) and run their office with little interference. Likewise, the broker-agent model allows little direct control over workers. Brokers are independent businessmen and women who run their own office, and only they are licensed to sell real estate, not agents. Agents are independent contractors who provide services to brokers and usually work for commissions only. They help brokers find properties and buyers, and help coordinate many aspects of real-estate transactions (Bureau of Labor Statistics 2004). Likewise, the high turnover of real-estate

[82] Many of these firms sold both commercial and residential real estate.
[83] Many of these firms sold both commercial and residential real estate.

agents makes it expensive to establish complex work routines in the office and field. However, without routines it is even more difficult for a broker to control and coordinate the activities of brokers. A large majority of agents do not last more than a year (Bureau of Labor Statistics 2004; Farhar et al. 1997).

Bankers and attorneys usually have a substantial amount of early involvement in the process of buying residential property. Before buyers even start looking at homes through a realtor they typically choose a lender and become either pre-approved or pre-qualified for financing. Once clients find a house that they like, the realtor and often an attorney draft an offer to the owner via the realtor who is their listing agent.

Offers usually include a counter price to the listed amount, technical problems with the dwelling and property that need to be rectified as a condition to sale, exit clauses that can be invoked if financing is not obtained or if home inspectors find a problem with the property, and closing dates. If accepted by the seller, offers are legally binding. This is all common practice for realtors, bankers, and attorneys, but it initiates a set of routines involving a dozen or so other real estate professionals that will scrutinize the property to ensure that technology in the dwelling on the property meets the minimum standards of the community, government, and broader industry and also that it meets the expectations of the buyer.

Before the buyer can finalize the loan with his or her bank, the lender usually sends an appraiser[84] to assess the market value of the technology in the residential dwelling and of any land the dwelling may reside upon. The lender wants to be "reasonably sure the amount of the loan does not exceed the value of the real estate" (Boulder Real Estate Services, n.d., 20). Therefore, on behalf of the lender, the appraiser looks to see that the dwelling has the minimum of what a home in that market and community ought to have such as enough insulation in the attic and central HVAC, checks the physical condition of the property and that there are not any obvious defects in the house, and assesses the market value of the technology in the dwelling. However, the appraiser is usually not an expert in building technology, and a

[84] "The majority of real estate appraisals are requested by lenders to establish the property's value for loan purposes" (National Association of Independent Fee Appraisers 2004b).

great deal of the technology in an existing residential dwelling is not readily apparent from a visional inspection. It is located within walls, ceilings, and floors.

An appraisal value is arrived at through one or more of the below three approaches, all derived from the market. The first approach based on comparison with the sales price of other similar dwellings is by far the most common and preferred.

- **The comparison approach** to value "makes use of other 'bench mark' properties of similar" size, quality, location, and building technologies "that have recently sold." The prices that were obtained on their other properties are used to valuate the property in question.

- **The cost approach** to value "is what it would cost to replace or reproduce the improvements as of the date of the appraisal, less the Physical Deterioration, the Functional Obsolescence and the Economic Obsolescence. The remainder is added to the Land Value."

- **The income approach** to value is of primary importance in ascertaining the value of income producing properties, but has little weight in residential type properties. It is an estimate of what a prudent investor would pay based upon the net income the property produces (Moye 2004).

Appraisers prefer not to use the approaches based on "cost" and "income" for residential properties. As one appraiser pointed out, if an appraisal firm cannot find a "comparable" for a particular technological feature of a home, they may assign little or no value to it. For building technologies that are uncommon in a community such as solar panels or straw bale construction, this may be a deterrent to their purchase.

Of course, mortgage lenders are not specifically in the business of facilitating technological change. Their primary concerns are selling mortgage financing as quickly and efficiently as possible, and minimizing the risk of default on the loans they make (Boulder Real Estate Services, n.d., 20; National Home Builders Association Research Center 2001b). New or old technologies are not *per se* good or bad to mortgage lenders. The main concern is the market valuation of a technology, specifically if a building technology lowers the value of the home below a requested loan amount (National Home Builders Association Research Center 2001b). However, if an appraiser locates a technical problem with a home such as “attic with no insulation” that would make it worth less than the requested loan amount, lenders may act as a rearguard to technological change. One option for them is to help arrange for either the buyer or seller to finance of the needed repairs or improvements (suggested a loan officer during an field interview). However, if mortgage lenders are asked to loan money for a home with radical new building technology that they view as unproven and risky, they may decline the loan.

The firms that sell mortgage financing to homebuyers are usually large, national banks with branch locations in thousands of communities. The responsibility and training that is given to loan officers that interact with homebuyers are actually the equivalent middle managers or sale reps in other industries. Most loan officers are paid a salary and often a small commission or bonuses based on the number of loans they originate (Bureau of Labor Statistics 2004).

Home inspectors are usually better trained at building science than appraisers. A standard home inspection summarizes “the condition of the subject home’s heating system, central air conditioning system (temperature permitting), interior plumbing and electrical systems; roof, attic, and visible insulation; walls, ceilings, floors, windows and doors; foundation, basement, and the visible structures of the home” (American Society of Home Inspectors 2005). Also, some owners will call specialists in heating and air conditioning or electrical systems, or other experts if homes have septic tanks and if problems are suspected with radon or underground storage tanks.

Home inspectors are paid to look out for the interests of the buyer, and most contracts with the seller do not become binding for the buyer until a home inspector certifies the dwelling is free of major defects or that defects will be fixed (Bureau of Labor Statistics 2004; Boulder Real Estate Services n.d.). Again, the job of home inspectors is to find problems with existing technology and locate technologies that are missing but that the dwelling should have based on community norms and building codes, such as an attic without insulation or a defective furnace. Their job is not officially to recommend alternative technologies although informally some do.[85]

Technological change can be facilitated in other ways at the time of real-estate transactions through ordinances and voluntary programs. A few jurisdictions require "time of sale" changes of technology such as replacing "older toilets with [new] ultra-low-flush toilets" (Marin Municipal Water District 2005). Some cities have started to require time of sale inspections from independent third parties to identify and replace hazardous technologies (City of Bloomington 2005). Also, Southern California Electric offered "time-of-sale" energy audits to its utility customers during real-estate transactions as an optional part of a home inspection that were followed by recommendations of energy saving measures (Ridge & Associates 2002).

A licensed real-estate attorney will usually handle the closing between the buyer and seller. The attorney will check to make sure that all of the conditions of the contract have been fulfilled including legal requirements that vary by the jurisdiction and the prerogatives of the buyer, but almost always include a final assessment of past technological choices. They can include copies of water [fuel, and electricity] bills, certificates of compliance with laws pertaining to smoke-detection equipment and lead paint, and also results of termite, septic tank, and radon inspections.

Conclusion

The existing construction side of the residential housing industry appears to be slowing down technological change in the overall industry. When technological change does occur on the existing housing side, it seems to be through conservative, autonomous innovations to bring substandard housing units up to community standards.

Although this review is not able to determine the nuanced motivations of all the industry participants for this technological change, it does allow insights into their structural interests. Mortgage lenders and home buyers seem to have a structural interest in this technological change to protect their investment and themselves from harm. Firms and organizations such as home inspectors, appraisers, attorneys, code

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[85] Tom Conlon, Geopraxis, August 2000.

enforcement agencies, and various other consultants and experts make a profit assisting lenders and home buyers with technical and financial advice. They have a structural interest in providing this professional assistance for a profit. On the other hand, it seems that the primary structural interest of sellers and realtors is simply to sell existing homes as quickly as they can and for as much as they can. If bringing homes up to the standards of the community is needed to make a sale, then they have a structural interest to encourage this.

There seems to be additional structural resistance to more radical, systematic innovation on the existing housing side of the industry. This is in part because existing homes are difficult to retrofit, but there are other reasons. The existing housing side of the residential housing industry appears to have few of the necessary organizational capacities for facilitating systematic innovation. Instead it seems to be populated by an even more fragmented, decentralized set of small firms and organizations than on the new housing side that are coordinated by a decentralized structure of norms, standards, traditions, contracts, regulations, codes of ethics, and network relationships. While these decentralized structures seem to be very useful for completing real estate transactions with an acceptable amount of speed and efficiency as well as facilitating conservative autonomous technological innovation, these are likely much less useful for introducing systematic innovations.

The introduction of systematic innovations seems to require that the fit between an invention and the larger system is evaluated and then adjusted to increase the fit so that the invention will be an easy to use and common sense part of the sociotechnical system. From what was learned in Chapters 3 and 4, centralized structures are needed for strategic planning, evaluation, and oversight, as well as collection of information, control, and coordination of relevant parts of the system to fit systematic innovations into the existing systems arrangements.

All these characteristics make it difficult for policy makers and participant-advocates to intervene at the "point of sale" in real-estate transactions and influence the adoption of systematic innovations. It appears the firms on the existing housing side might not have enough organizational capacities to control and coordinate enough of their own industry to assist policy makers and participant-advocates in the introduction of systematic innovations.

Chapter 9: The Pilot Study of Home Energy Rating System and Energy Efficient Mortgages

Participant-advocates of home energy ratings (HERS) and energy efficient mortgages (EEMs) have been attempting for the last two and one half decades to fundamentally restructure how energy technology is chosen by participants on both the new and existing construction sides of the residential housing industry. The participant-advocates of HERS have been experiencing some success. In 2004, approximately 10% of new construction was HERS rated to be 30% more energy efficient than MEC 92, which is one of the most common set standards for building codes. HERS ratings are on the cusp of having a major structural influence on the residential housing industry. However, EEMs have fallen considerably short of achieving a similar impact on the industry. This chapter and the next are a case study of both HERS and EEMs, and it will be used to evaluate the thesis that *too few organizational capacities for system building by progressive advocates of technological change has been a reason for not successfully developing alternative technology into marketable products.*

This chapter takes a “bird’s eye view” of how effectively both HERS and EEMs were integrated into the residential housing industry at a national level. As mentioned, both HERS and EEMs are highly systematic social innovations. Both of these innovations had great difficulty in the 1990s in part because system-building organizations that promoted them had few capacities for centralized information collection, control, and coordination of their integration into the residential housing system. This was in stark contrast to the speed, efficiency, and effectiveness that corporate R&D projects integrated new innovations into their relevant sociotechnical systems, such as was exemplified by DuPont’s development of nylon into a marketable product.

One-hundred-and-thirty-thousand newly constructed homes were assigned a HERS rating in 2004, which were primarily used by builders to monitor the quality of construction to lower warrantee claims, and to market the quality of their new construction to home buyers. As mentioned, HERS ratings are state-of-the-art assessments of the energy efficiency of dwellings that use field inspections to gather data and computer modeling to estimate energy use and then produce efficiency ratings. These ratings are a performance-based measure of energy efficiency in contrast to “Good Cents” and “Super Good Cents” programs that merely use a check list to assess how many energy efficient features a dwelling has.

Energy efficient mortgages give people better terms on their financing if they purchase a house that is energy efficient. If people buy an existing home, EEMs allow them to borrow additional money to make energy improvements and sometimes offer them better terms on their loan. Few EEMs have been used. The complexity and extra time it takes to complete the EEM process relative to the benefits and incentives seems to deter their use.

Of course, other organizations and programs have encouraged alternative building technology through system building or related activities. These include Good Cents and Super Good Cents, which are utility programs for labeling new construction as energy efficient, Leadership in Energy and Environmental Design (LEED) to construct green buildings, which is a program of the U.S. Green Building Council, Building America (a program of the Office of Energy Efficiency and Renewable Energy at the DOE) takes a team approach to R&D, design, and construction, and Public-Private Partnership for Advanced Housing Technology (PATH) works with industry to introduce into the marketplace a wide range of new building technologies, which is a program of HUD.

The Lack of Fit

It was mentioned that HERS and EEMs advocates are part of a broader participant-advocate network of green builders. Before we focus in detail on HERS and EEMs, it will be instructive to consider the challenges of the broader green building effort.

Currently, there are hundreds of devices, materials, and techniques to make housing more energy efficient, last longer, and improve comfort and air quality. Despite much of it being technically and economically feasible, most have had little market success (DOE/BTS 1999). If used more frequently, technologies such as super insulation, high-efficiency HVAC systems, and airtight construction could greatly improve the energy efficiency of new and existing housing. Also, there are builders and contractors who can deliver green technology that is cutting edge. Solar Unlimited, Inc. can build a home with photovoltaics, solar water heaters, and composting toilets that is likely to be cheaper than hooking up to the grid for many rural residents (Daniel and Whipple 2005). Homebuyers can also choose to call up Terrasol Design and Building to order a straw-bale home that will last a century (Glenn 2005).

Why are these technologies and building systems not more widely used? Are homeowners and buyers irrational? Is it the fault of the builders? While these answers might be tempting, we cannot place all of the blame on the homeowners and buyers. The answer is more complicated. The above technologies are not well supported by the larger sociotechnical system, and it is arguably more rational than irrational to choose conventional technologies.

If you hope to finance the construction of a straw-bale home and purchase homeowners insurance, you will likely have difficulty. You will likely have to shop around and sell your idea to the rest of the housing industry. Getting the building permit might be the most difficult (Glenn 2005; Info for Building 2005). Likewise, if you want to install windmills or solar water heaters, you may not have a contractor to install and service these in your community. Given the extra hassles of buying these technologies, installing them, additional up-front costs, occasional snide remarks from relatives and friends, and uncertainty about resale value, it is perhaps no surprise that homebuyers and owners typically choose conventional technologies (also see Farhar, Collins & Walsh 1996; Farhar and Eckert 1993; Lutzenhiser 1992; National Renewable Energy Laboratories 1992a).

However, it is not the fault *per se* of lenders, appraisers, or code officials. Many housing professionals lack hard evidence about the durability and resale value of alternative technologies, without feasible mortgage products and the use of appraisal methods that reflect the true benefits of these technologies. Nor can perceptions be entirely attributed to individuals. Our culture holds persistent attitudes and values about the kinds of materials from which a home should be constructed, how it should be constructed, and how it should look.

The problem *per se* is not the pieces of technical hardware or the individuals. Instead, it is the larger sociotechnical system that supports certain types of technology over that of others and that shapes the decisions and behavior of individuals. There appears to be a substantial amount of latent demand for many energy-saving, alternative technologies (Farhar 1994) that could be realized if the relevant sociotechnical system was structured differently.

The advocates of HERS and EEMs want to reshape the system to do just that. Although most of the technologies that are actually being placed into homes through the use of HERS and EEMs are much less radical than composting toilets and photovoltaics, advocates of HERS and EEMs have long-term plans for some of technologies as well (National Renewable Energy Laboratory 1992a).

Beginning years for HERS and EEMs

The first HERS and EEMs have been around since at least the early 1980s. They existed as two separate initiatives, and did not attract much attention from each other or from other energy efficiency professionals, industry, and government. The early HERS advocates were intent on developing a rating system to provide accurate information on the energy efficiency of homes for consumer labeling, to meet energy codes, to aid decisions about retrofits, and to appraise of the market value of energy efficiency in homes (Luboff 1995; National Renewable Energy Laboratory 1992a; Farhar et al. 1997).

Early EEM advocates included bankers who were aware that rising energy costs and interest rates could undercut the ability of individuals to pay for housing costs and finance the purchases of homes (Colorado Housing and Finance Authority 1998). The Federal Home Loan Mortgage Corporation wrote:

> [we are] concerned about the impact that rising energy costs are having upon the financial stability of homebuyers . . . Lenders must also take into consideration the energy efficiency of properties, especially energy efficient items which reduce energy costs and permit a greater portion of borrowers' income to be applied to housing expenses (Schaefer 1980, 24).

They also knew that up-front investments in energy efficiency were difficult for homebuyers. Homebuyers tended to use all their borrowing power for as large of a home with as many amenities as they could afford, and then have nothing left over for energy efficiency. However, the early advocates believed a mortgage product could be designed to encourage these investments. They reasoned that energy efficiency would pay for these extra up-front costs over time, and thus buyers should be allowed to borrow more money for these extra up-front costs. Borrowers would be able to afford a better house, and lenders would be able to make larger loans for no extra risk (Luboff 1995; National Renewable Energy Laboratory 1992a; Farhar et al. 1997).

In 1979 President Carter signed an executive order directing the four federally chartered mortgage lenders and insurers—Fannie Mae, Freddie Mac, Federal Housing Administration, and the Farmers Home Administration—to develop consumer incentives within the mortgage process to encourage energy efficiency (National Renewable Energy Laboratory 1992a). Freddie Mac's approach to energy efficient mortgages was to allow lenders to finance energy improvements through mortgages for existing homes, extend the loan-to-value ratio by 10% for the appraised value of the house with energy improvements, and include the reduced costs of energy in the underwriting process (Schaefer 1980). Fannie Mae's guidelines called for a direct 2% increase in qualifying ratios for homes identified as energy efficient, which became the norm for the industry during the 1980s (Luboff 1995).

No more than a handful appears to have been used nation-wide. There were two major problems. *First*, there was no accurate way to estimate energy costs. *Second*, there was no agreed upon way to appraise the market value of energy efficiency in the real estate market.

Both problems were recognized by Henry Damus of the University of Washington's Western Resources Center and by a group of bankers. They created a rating system that would assess the energy efficiency of a home and estimate energy usage. Out of their efforts grew the first home energy rating system that later took the form of the non-profit Energy Rated Homes of America (Luboff 1995).

The HERS system that these individuals developed was a *performance based* assessment of a home's energy efficiency. This was new. Other methods such as "Good Cents" were *prescription based assessments* where items on a list are "checked off" to see if a home contains the features that theoretically should result in a certain level of efficiency. Performance is (and was) determined by measuring how air tight a home is, estimating the thermal barrier of construction materials, calculating solar gain, and identifying the efficiency of HVAC equipment. This data is then used in a mathematical model to estimate energy use (Farhar and Eckert 1993).

HERS ratings were potentially transformative of the residential housing industry if widely adopted because these ratings had the potential of fundamentally changing how the industry made choices regarding energy technology. Accurate information from the ratings could be used in consumer labels for homes, in the mortgage underwriting process for both new and existing homes, to demonstrate compliance with energy codes, and to inform decisions about retrofits. Furthermore, HERS ratings held the promise of accurate information about not just energy efficiency per se, but also the quality of the overall construction. Unlike any other industry that makes complex technological products, homebuilders have lacked an in-house quality control system of any sophistication. Thus, HERS ratings offered something new—a quality control program that provided direct feedback to builders about the quality of their workmanship, choice of materials, and design. It has been difficult for builders to design and build high quality and energy efficient homes with no measure of efficiency to assess their work.

However, most energy efficiency professionals in the 1980s preferred policy approaches rather than HERS or EEMs. The dominant paradigm was demand-side management (DSM), which focused on changing the behavior of consumers, not industry participants. The assumption was that homeowners and homebuyers were rational economic actors. If accurate information was provided about how to make homes more energy efficient and the economic savings that would result, it was expected that they would purchase and use energy efficient technology**.**

It was not until 1986 that Energy Rated Homes of America (ERHA) was incorporated and began training, licensing, and supporting others to use their proprietary HERS rating tool called “E-Z rater.” ERHA was able to set up HERS programs in Arkansas by 1986, Vermont by 1987, and Virginia, Iowa, Rhode Island, and West Texas by 1992. There were other HERS systems as well. In 1986, the state of Alaska developed their own HERS software that was specific to their climate. Also, the cities of Austin, Texas, and Fort Collins, Colorado, and a number of states developed their own HERS software in the late 80s and early 90s (National Renewable Energy Laboratory 1992a; Farhar et al. 1997; Vories 1991).

In the early 1990s, all of these HERS programs were still heavily subsidized so ratings could be provided either for free or at a reduced cost. The idea was for HERS programs to become market driven, but most homeowners, buyers, or builders were not yet willing to pay the full cost for the information about energy efficiency that was provided by a rating (Farhar et al. 1997; Edmunds 1997).

A few HERS professionals confided in interviews during the case study that many or most of the HERS ratings done in the 80s and early 90s did not result in any action being taken to improve energy efficiency (see Rieger 1993; Farhar et al. 1997 for similar comments). The problem was that homeowners and builders were having HERS ratings conducted because it was free, not because they had a real intention or the ability to use the information from the rating to improve energy efficiency. Usually, when HERS ratings were conducted, the resulting information was not plugged into the processes of technological choices were decisions were actually made—not into EEMs, the design and construction of homes, the sale of homes, or code compliance. The task of actually integrating HERS ratings with the mortgage process and into the other day-to-day routines of the housing industry went far beyond the abilities of early HERS and EEM advocates. There still was not a basic institutional and organizational infrastructure for HERS and EEMs to be feasibly and widely used. The use of HERS and EEMs grew slowly. Only about 10,000 homes were rated nation wide between 1986 to 1991[86] and only 20,000 EEMs were completed between 1980 to 1990 (0.028% of the total number of mortgages) (Vories 1991).

However, the 1990s would be more generous with organizational, political, and financial support for EEMs and HERS. Policy makers were becoming frustrated with trying to change the technological choices of builders through heavy-handed regulatory codes, fruitless attempts at educating homeowners through direct mailings, and offering rebates and tax credits to people that probably would have purchased energy efficient technology even without these incentives. The United States would be looking for new, market-driven policy tools.

[86] Energy Rated Homes of Vermont rated about 1,100 homes from 1987 to 1991 (about one percent of total home sales); Rhode Island rated 3,300 homes by 1991; Energy Rated Homes of Texas rated 2,000 homes by 1991; Energy Rated Homes of Alaska rated 3,300 from 1986 to 1992; (Vories and Davis cited in Farhar and Eckert 1993); approximately 500 were rated by Energy Rated Homes of Arkansas form 1988 to 1991 (Farhar, Collins, and Walsh 1997).

A National Effort

In the early 1990s, HERS and EEMs gained the attention of a broader set of energy professionals, the DOE, and federal politicians. A national effort was about to emerge, and in a few short years HERS and EEMs would become part of the National Energy Policy and mentioned in the national platforms of both major political parties.

However, there were significant problems that needed to be resolved. HERS and EEMs programs had been evolving in many localities in isolation from the rest of the country, which resulted in substantial variation in HERS and EEM programs. This was counterproductive to creating a coherent system in the national housing market (Home Energy Online Magazine 1997). While variations in HERS and EEMs were flourishing, the home building and the mortgage market was becoming increasingly standardized and national in scope. HERS and EEM advocates knew that this was a problem that would hinder the linkage of HERS ratings to EEMs and to the rest of the system.

> . . . the local variation in programs makes it impossible to build a universal link between HERS and a national EEM program. Further, most HERS use different calculation approaches, or ‘tools’ with little or no documentation of technical accuracy. In fact, technical standards for HERS have never existed. Lenders and others have questioned the reliability of energy-use and savings estimates generated by HERS (National Renewable Energy Laboratory 1992a, 16).

The National Collaborative

In 1991, the Department of Energy (DOE) and Department of Housing and Urban Development (HUD) took facilitative roles. They convened the *National Collaborative on Home Energy Rating Systems and Mortgage Incentives for Energy Efficiency*. This provided a catalyst for HERS and EEM advocates and their industry supporters to self-organize a more unified, coordinated effort (Vories 1991).

“The mission of the collaborative was to reach a consensus on a voluntary national program that will link” and standardize HERS with EEMs and with the rest of the residential housing industry. Participants in the Collaborative were representatives of 25 organizations in the primary and secondary mortgage markets, builders, remodelers, realtors, appraiser trade associations and firms, utility associations, consumer groups, environmental organizations, state and local governments, SEOs, and of course HERS and EEM participant-advocates. The Collaborative met 10 times from 1991 to 1992, and generated proceedings called *A National Program for Energy Efficient-Mortgages and Home Energy Rating systems: Blueprint for Action* published by the National Renewable Energy Laboratory in March 1992, which is often called the *Blueprint for Action* (National Renewable Energy Laboratory 1992a, iv).

A high degree of consensus was reached on most of the general problems faced by HERS and EEMs. The National Collaborative identified those parts of the emerging HERS and EEMs infrastructure that needed to be added, reshaped, or eliminated. The only major disagreement was on how energy costs should be incorporated into the mortgage process. The non-lenders wanted a generous valuation of energy improvements and monetary savings to be used in the appraisal and underwriting process. Lenders insisted on more cautious assumptions (National Renewable Energy Laboratory 1992a; 1992b). The problems and solutions upon which there was agreement are listed below.

Problem 1: No information about energy efficiency: There was not an accurate source of information about the actual energy efficiency of homes for builders that want to build efficient dwellings, buyers who wanted to purchase an energy efficient house, nor for homeowners who wanted to retrofit.

Solution 1: Build a nation-wide, organizational and institutional infrastructure for HERS ratings.

Problem 2: Up-front costs of energy improvements: The initial costs of energy efficient technology can prevent homeowners and buyers from purchasing it in the home buying process.

Solution 2: Make EEMs available in all U.S. markets and allow money from future energy savings to be included in the underwriting process, a value for energy-efficiency into the appraisal of real estate, and no additional down payment when borrowing for energy improvements. If additional down payments are required, allow third parties to provide assistance.

Problem 3: No standardization and integration among EEMs and HERS: All ratings systems do not generate the same information outputs, in a form that can be included in the underwriters' process, and that is usable by appraisers to evaluate energy-efficient homes.

Solution 3: Redesign and standardize the various rating systems and their information outputs.

Problem 4: Perceived risk by the secondary mortgage lenders from amortizing the full costs of energy-efficient technology: There is little or no information on the default rates of EEMs, the accuracy of the HERS to predict energy savings, and the market value of energy efficiency.

Solution 4: Collect and analyze data on default rates, energy consumed, and market value.

Problem 5: Mortgage limits: All existing EEMs have maximum amounts of money that can be borrowed because the secondary mortgage lenders who sponsor them are regulated by Congress. This makes EEMs unsuitable for the large majority of homes that are bought and sold.

Solution 5: Modify the law to allow higher limits on mortgage products offered by the Federal Housing Administration, Fannie Mae, Freddie Mac, and Veterans Administration.

Problem 6: Insufficient knowledge and skills for using HERS, and EEMs by housing professionals.

Solution 6: Organize training programs for housing professionals.

Problem 7: No standardization of EEM products: The four lenders offering EEMs used different documents and deadlines for starting an EEM and the installation of improvements.

Solution 7: Fannie Mae, Freddie Mac, Veterans Administration, and the FHA will attempt to establish a consensus about how to make their mortgage products more uniform.

The primary disagreement was about solutions to problem 2—how to deal with the up-front costs of energy improvements through the mortgage process. Lenders were reluctant to give additional benefits and incentives for EEMs. They were skeptical that energy efficiency in homes had additional market value, and did not want to lend extra money for energy efficiency that was not secured by additional collateral and covered by mortgage insurance. They insisted that the loan amount should not exceed the market value of a home, and were doubtful that the predicted energy savings by HERS ratings would be realized. They were also reluctant to not increase the down payments required for lending additional money for EEMs. Down payments are one of the largest stumbling blocks for homebuyers, but the best predictor of who will not default (National Renewable Energy Laboratory 1992a).

HERS Organizations and EEM Participant-advocates: Capacities for System Building

The National Collaborative was meant to be temporary. Once finished, the leadership among HERS and EEMs advocates took the form of two permanent bodies that had nominal organizational capacities for coordinating system-building activities. The HERS Council was a private organization funded by the DOE, and the HUD task force was an interagency government committee.

The HERS Council formed immediately after the National Collaborative ended, and secured on-going financial support from the DOE (Farhar and Eckert 1993). Its membership mirrored the Collaborative and by June 1993 it was at one-hundred-and-six. It was charged with overseeing and developing solutions that came out of the Collaborative, although it mainly focused on developing a set of protocols and standards for HERS rating systems (Farhar and Eckert 1993). The HERS Council envisioned itself as a permanent, national organization that would

- continue to “develop and improve uniform HERS guidelines,”
- develop a link with EEMs, and
- educate the public about HERS and EEMs (Farhar and Eckert 1993, 8).

Were these system builders? Yes, the National Collaborative and the HERS Council were system builders. As mentioned in Chapter 2, for an organization to be considered an organizational system builder, it must 1) have the intention to reshape its relevant system and 2) it must have organizational capacities for system building. The first criterion is discussed below for the organizations that are being considered to be system builders. The evidence of their organizational capacities for system building is in the remainder of this chapter. However, as mentioned, I am not treating government as a system-building organization, but instead as a set of organizational structures and routines that are lobbied and deployed as part of the political process. The activities of government bodies, such as the DOE and HUD seem to be structured much more by political routines than by organizational routines for system building and likewise they appear to have a political l—to appease constituent groups—rather than for system building per se.

The comments of the staff and members of the National Collaborative and the HERS Council and what others have written about their ideas, strategies, and goals suggest that they were intentionally attempting to restructure the system and that they were aware of what it would require. Although they did not specifically use the phrase system builders to describe themselves, they were conscious of their efforts to restructure the existing system. They routinely spoke of the need to integrate HERS and EEMs into the residential housing industry. To do that, they understood the need to build a basic institutional and organizational infrastructure, and then incorporate the use of HERS and EEMs into the day to day details of the industry. They knew that they had to change some of the fundamental ways in which housing professionals and homebuyers/owners made technological choices (see National Renewable Energy Laboratory 1992, Farhar Eckert 1993; Luboff 1995; Farhar et al. 1997; and Faesy 2000).

Many of them knew that parts of the system were interconnected with each other, and that making changes to isolated parts of it would not help. In a telling exchange during the summer of 2000 I observed the HERS professional respond to a comment by a visiting congressman. The congressman suggested that the problem faced by energy efficient technology was that too few people knew about it. HERS professional responded,

> It is more complicated than that. There are many other reasons why people don't use energy efficiency. We are trying to transform the entire market . . . the way that people in the residential housing industry go about their business.

Other advocates of HERS and EEMs have stated similar.

> . . . states have tried to integrate energy efficiency considerations into the daily business practices of the housing finance, sales, and construction industries . . . with cooperation from the housing and energy efficiency industries, both the federal government and conventional lenders (Luboff 1995).

> . . . the goal of having energy ratings become a common part of the home buying and selling process, in the same way as appraisals and inspections are conducted" (Energy Rated Homes of Vermont cited

Farhar et al. 1997, 252).

The HERS Council was a small, young organization with very limited organizational capacities to coordinate a fragmented, decentralized group of organizations. The HERS Council had no direct control over the residential housing industry, but did have some influence over HERS and EEM advocates. The main source of influence that the HERS council had over the housing industry was to stress the benefits of HERS and EEMs to stakeholders and homeowners. The minimal staff time and financial resources of this group also placed constraints on their organizational capacities to gather information about, plan, control, coordinate, and fund system-building activities. It had few staff at any particular time.

Nevertheless, the HERS Council did appear to have some *capacities for strategic planning and the control and coordination* of other HERS organizations and EEM advocates. Little information was available on their specific routines, but some was available on its general set of routines. Much of these capacities appear to have been through their consensus building, voluntary, network approach to system building. More than anything, they acted as a forum to attempt consensus about how to build an infrastructure for HERS and EEMs, and an impetus for new HERS organizations to form. While the Council itself had few in-house organizational capacities to interact with and influence the larger system, other HERS and EEM participant-advocates and industry participants did have these capacities. The members of the Council were parts of dozens of organizations (among HERS providers and in industry, government, and the non-profit sector) that did have significant organizational capacities for system building through network relations with its member groups. However, the HERS Council had no direct control of these and could only loosely coordinate the activities of these member groups who were often involved in many activities other than HERS and EEMs.

To some degree it appears that the HERS Council was to coordinate some of the activities of its member groups. Doing so consisted of a very simple set of routines to organize and hold periodic meetings, to evaluate the current state of the system and plan what needed to be done, and agreed upon procedures for reaching actionable consensus. When consensus was reached, action was voluntary but it appears that the volunteers were often highly motivated professional staff in other HERS organizations, industry associations, utilities, and government agencies. Some system building tasks were easier for the HERS council to accomplish than others. The fact remains that HERS and EEM participant-advocates were still a very decentralized, fragmented effort—initiative and ideas bubbled up from the bottom to be deliberated at the top where consensus was sometimes reached on what needed to be done, and volunteer actions that needed little coordination often resulted (Farhar and Eckert 1993; Farhar et al. 1997; National Renewable Energy Laboratory 1992b).

The HERS Council had some ability to lobby government, but aid lobbyists do not appear to be significantly involved. Lobbying was mostly conducted through grassroots efforts by staff, members, and volunteers of the HERS Council by keeping in contact with elected and appointed officials as needed. The National Collaborative and its members are “known to have influenced” the national energy legislation that helped build an infrastructure for HERS and EEMs. Other groups that participated in the collaborative, such as the National Resource Defense Council, also lobbied the federal government (Farhar and Eckert 1993, 2). This is pushing the minimum criteria for organizational routines and capacities. However, other lobbying activities were more *routine.* Specifically, HERS Council members had rather routine access to mid-level government bureaucrats, program managers, and field staff in DOE and HUD by sitting on committees/task forces with them and going to the same conferences (National Renewable Energy Laboratory 1992; Farhar and Eckert 1993).

Also, when the federal government convened the National Collaborative, it gave legitimacy to HERS and EEMs, and appears to have led to greater cooperation by the housing industry. Social legitimacy is not *per se* an organizational capacity, but instead is an aspect of the larger system. However, Weber (1947; 1978) and others have convincingly argued that legitimacy and power/control go hand in hand. By legitimizing HERS and EEMs and thus the National Collaborative and the HERS Council, the government likely increased the effectiveness of the very limited capacities of the National Collaborative to persuade others to use HERS and EEMs, cooperate in their use, and to help promote them.

Both an indicator of and a source of this legitimacy was the dramatic increase in media coverage about HERS and EEMs after the National Collaborative. From 1980 to 1990, HERS and EEMs were mentioned only 7 times in print media. During the nine year period of 1991 to 1999, these were mentioned approximately 155 times—19 articles in major newspapers and magazines, 32 in newsletters, and 104 in business news publication.[87] There was also a mention on "This Olde House" and other television and radio programs, and coverage by local media.

Of course, legitimacy does not automatically translate into control and influence, unless organizations have the organizational routines to communicate and interact with others. HERS organizations did have fairly substantial routines to promote HERS and EEMs to the housing industry and general public, which will be discussed in the next chapter. For the moment it suffices to state that on a fairly regular basis they were able to release press statements, write or interviewed for articles in newspapers, magazines, and news letters, attended forums, made presentations, organized sessions at conferences and conveyed a message that stressed the financial, social, and environmental benefits of HERS and EEMs to targeted audiences. Also, they spent a significant amount of staff time writing grants, assisting the development of new HERS programs, recruiting raters, and training lenders about EEMs (see examples in Farhar and Eckert 1993; and Farhar et al. 1997).

It needs to be mentioned that the HERS Council and the HUD task force were not the only national actors. The DOE and HUD will be discussed below. Also, Energy Rated Homes of America (ERHA) was setting up HERS systems in a number of states and actively trying to sell licenses to new HERS organizations for their rating software.

Also, at the state level, there were other organizations that provided initial leadership. State housing and finance agencies (SHFC), state energy offices (SEO), and utilities were very important in assisting the start up of HERS organizations. This included significant financial support, efforts to promote EEMs, and helping the HERS organizations make contacts with the broader housing industry (Roitsch 1992; Farhar and Eckert 1993; Farhar et al. 1997; Farhar et al. 1996).

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[87] This information was determined from a search of the Lexis Nexis database in the summer of 2003.

While reasonably effective at some types of system building, the HERS Council was essentially useless at other types. Through routines for consensus decision-making and voluntary actions from like-minded organizations, their efforts were usually sufficient to build a basic organizational and institutional infrastructure for HERS and EEMs. However, they would run into considerable difficulty trying to integrate these new organizations and institutions into the day-to-day activities of the housing industry.

Laws, Standards, New Organizations, and Awareness Campaigns

With help by the DOE and HUD, the HERS and EEM advocates placed a few recommendations from the National Collaborative into three pieces of federal legislation (Farhar and Eckert 1993).

> The Housing and Community Development Act of 1992 (P.L. 102-550) directed HUD, to form a HUD task force to examine options for a uniform EEM program that linked EEMs to HERS, to implement a five-state pilot study of EEMs for existing construction, and also for the Secretary of HUD to make a recommendation on the feasibility of a nation-wide EEMs program that used HERS ratings to verify energy efficiency.
>
> The National Energy Policy Act (EPAct) of 1992 (P.L. 102-486) required the DOE to develop guidelines for uniform, voluntary home energy ratings systems that would provide an important institutional structure for the emerging HERS organizations. EPAct also directed the DOE to evaluate the effectiveness of the HERS systems in the five-state pilot study of EEMs
>
> The Veterans Home Loan Program Amendments of 1992 (P.L. 102-547) would mandate a 3-year pilot program exploring the feasibility of EEMs for existing housing through loans to veterans.

These three Acts of Congress merely authorized and provided funding to establish institutions for HERS and EEMs and to help fund the start up of HERS organizations. However, EEM and HERS advocates needed to actually build those institutions and organizations. Both of these activities proceeded simultaneously. Even without fully legitimated national guidelines, the organizational basis of HERS ratings started to spread across the country and become more standardized.

Setting Voluntary, Uniform HERS guidelines

Through the passage of EPAct of 1992, Congress directed the DOE to promulgate a set of uniform, voluntary standards for HERS systems. In turn, the DOE contracted with the HERS Council to develop and recommend a set of standards. Although they had opposition from gas utilities, the HERS Council established consensus fairly easily among HERS professionals and the rest of the housing industry.

In 1993, the National Association of State Energy Offices (NASEO) worked along side the HERS Council to develop the standards. They produced and recommended a set of standards to the DOE Office of Energy Efficiency and Renewable Energy (EERE). These standards contained:

- Protocols, procedures, and standards for the
  - certification of HERS software/rating tools
  - accreditation of HERS providers
  - training of HERS raters
  - collection of on-site data about houses
  - standardization of rating reports
  - quality control of individual raters
  - monitoring and evaluation of the accuracy of the HERS systems relative to actual energy use and costs.
- Mechanisms to consistently link HERS with EEMs.
- Flexibly take into account local climate conditions and construction practices, solar energy collected on-site, and the benefits of peak load shifting construction practices.

The DOE followed the recommendations of the HERS Council and NASEO when it published its "proposed guidelines in its 1995 notice of rule making" in the Federal Register (Residential Energy Services Network 2005).

However, a political battle ensued over the guidelines between the natural gas utilities and HERS organizations (American Council for an Energy-Efficient Economy et al. 1997) leaving the DOE in the middle. During the comment period, the natural gas utilities intensely criticized the DOE over the perceived fairness of the HERS guidelines. They thought the guidelines gave an unfair advantage to electric heating sources. The natural gas utilities also drew Congress into the conflict, and convinced the DOE not to promulgate the Voluntary Home Energy Rating Guidelines, despite pleas to do so from HERS organizations, NASEO, NHBA, and electrical utility industries (Fairy et al. 2000).

This was a major setback for HERS advocates and several negative consequences appear to have resulted. *First*, there was likely a set back in credibility. HERS advocates were depending on the HERS guidelines to give their HERS ratings credibility and move their system forward. *Second,* according to some observers, the lack of guidelines endorsed by the DOE resulted in less demand for HERS ratings among builders. *Third*, the DOE completely eliminated funding for the HERS Council and significantly cut funding for other HERS organizations. The HERS Council closed its doors in 2000. Some HERS advocates and allies suggest these consequences were a direct result of the conflict (Fairy et al. 2000; National Association of Home Builders 2005b; Boyson 2000).

The damage was somewhat abated in 1999 when NASEO adopted the voluntary HERS guidelines (Fairy et al. 2000). RESNET took over the task of further developing HERS standards, and in 2002 published the amended "Mortgage Industry National Home Energy Rating Standards" that was also endorsed by NASEO (Residential Energy Services Network 2002). The new standards were more developed in the following areas:

- The link between HERS and EEMs
- Rater certification
- Standards for administration of HERS systems
- Rater conflict of interest documents
- Accreditation of rater trainers

Summary: By the end of the 20th century, the advocates of HERS and EEMs had been reasonably successful at building a basic institutional and organizational infrastructure to support HERS and EEMs.

The use of consensus decision-making and motivating voluntary actions as the *capacities for strategic planning and evaluation, or control, and for coordination* proved sufficient among HERS organizations and stakeholders that had common interests. However, these capacities proved next to useless for controlling and coordinating those with divergent interests such as the natural gas industry.

Organizational Infrastructure

Even before uniform, voluntary HERS guidelines were adopted by NASEO, the advocates of HERS and EEMs had been setting up new HERS providers around the country. When the National Collaborative was meeting during 1991, there were approximately 10 HERS organizations run by non-profits and as programs of SHFC, SEO, and utilities around the country. By 1993, there were a total of 15 HERS organizations, and another 9 government or non-profit entities working to establish a HERS program (Farhar and Eckert 1993). By 1999, HERS programs were in 47 states and the District of Columbia. Although the actual service areas of these HERS programs was much smaller, major strides were made toward offering HERS ratings nation wide (Plympton 2000; Farhar 2000).

SEOs, SHFCs, city governments, utilities and (until the late 90s) the DOE were instrumental in starting these programs (Farhar and Eckert 1993). In addition to significant funding, they lent office space, employees, credibility, expertise, and industry contacts. A large majority of the staff at early HERS programs came from DSM and low-income weatherized programs that worked closely with SEOs.

From one point of view, it was a fairly easy thing to set up these HERS organizations, and from another point of view it was extremely difficult. There were already many HERS programs around the country to use as a model. By the mid-1990s, it was already becoming a fairly turnkey process of purchasing a license for HERS software, setting up an office, hiring and training staff, and opening one’s doors to start offering HERS ratings. However, it was much harder to generate demand for HERS ratings and have the information from these HERS ratings actually result in improvements in energy efficiency. The use of HERS ratings still had to be integrated into the day-to-day activities of the housing industry, which will be discussed below from a national perspective and in much more detail in the next chapter.

Attempts at Coordination and Other National Activities During HERS-EEMs Pilot Study

As the National Collaborative was winding down, some members had expressed concern for the lack of coordination and failure to assign roles and responsibilities for tasks to be complete (National Renewable Energy Laboratory 1992a). This was prophetic. It was exactly these issues of control and coordination that would plague HERS and EEM advocates at the national level over the next eight years.

There was no centralized capacity for strategic planning and evaluation, gathering information, providing funds, controlling, and coordinating the expansion of HERS and EEMs, linking HERS and EEMs, and readjusting of fit as needed. The National Collaborative brought together a diverse set of housing professionals from the private, non-profit, and government sectors who were committed to HERS and EEMs. This seemed unprecedented to many participants, and created a fair amount of excitement and hope. However, many problems emerged.

The DOE, FHA, HUD Task Force and the HERS Council were probably the only four national organizations with any chance of planning and coordinating system-building efforts at the national level. However, both the DOE and HUD are part of the same larger organization, the Federal government, which is not treated as an organizational system builder in this analysis. Despite its impressive financial resources and authority, the fragmentation of the Federal government into different departments, agencies, bureaus, and offices, and its saturation with political routines make it very difficult for it to successfully plan, evaluate, control and coordinate successful system-building efforts, as discussed in Chapter 2. Politics best explains its actions, not system building.

The Department of Energy: The DOE has traditionally been well funded, and the lion's share of the funding for HERS in the mid 1990s was from the DOE through EERE, and it funded the five-state pilot study of HERS and EEMs for a total of $750 thousand. Also, the National Renewable Energy Laboratory (NREL) within the DOE conducted program evaluations of HERS and EEM activities, and developed the BESTEST software to evaluate HERS tools to ensure compliance with national standards.

The FHA of the *Department of Housing and Urban Development* was the source of one of the most commonly used EEM products—the FHA EEM. The FHA did make important contributions to the

HERS and EEM effort by offering this EEM, but the FHA devoted very little staff time and resources toward promoting and further developing it. This was, in part, because Congress did not allocate additional funding to HUD to promote EEMs (Farhar et al. 1997) and because the FHA feared that EEMs were financially more risky to them than other mortgage products (O'Sullivan 1997). Nevertheless, some of the HUD field offices devoted their time to promoting EEMs even without encouragement or additional funding from top FHA or HUD administrators (Farhar et al. 1997).

This general lack of commitment to EEMs is best described by a story that was told by an EEM advocate about an encounter with a congressman.[88] The advocate expressed his frustration to the congressman that the federal government was not doing much to promote EEMs. To his great frustration, the congressman said

> “those are what we call ‘drawer programs.’ When someone comes into my office and asks what we are doing for energy efficiency, I tell them that I have something right here. I open up the drawer . . . pull out some information on energy efficient mortgages.’”

The HUD task force: An interagency committee composed largely of government employees—was created by the National Affordable Housing Act of 1990 (P.L. 101-625) section 946). to make recommendations to the Secretary of Housing and Urban Development on “a uniform plan to make housing more affordable through energy efficient mortgages.” The task force was formally made up of mid-level administrators and program managers from the DOE, HUD, Farmers Home Administration, Freddie Mac, and Fannie Mae, and informally of representatives of industry and HERS organizations to provide technical assistance. Once the task force made its recommendation of a uniform EEM plan to the secretary of HUD, it remained to coordinate EEM activities between government agencies (Farhar and Eckert 1993), although its influence faded.

The HERS Council: The Council is the only one of these organizations that we are classifying as a organizational system builder. It did have some organizational capacities that were occasionally at its

[88] This was not the same congressman referenced above.

disposal through its member groups, but it was largely on the side lines of the pilot project and study. Some of its members and volunteers were on the DOE pilot-study work group that helped structure the pilot project and study. They were primarily focused on developing technical standards and protocols for HERS rating systems. The organization did not devote much attention to broader system-building.

The emergence of HERS organizations and their advocacy for EEMs continued to follow a very decentralized model. By 1993, in addition to 15 HERS organizations, there were 14 major trade and professional associations from the residential housing industry, 3 associations representing utilities, 6 secondary mortgage lenders, 4 public interest groups, numerous SEOs, many SHFCs, and other state and local government agencies (Farhar and Eckert 1993) across the nation participating in this growing network of system builders to use EEMs and HERS. Their activities ranged from starting a new HERS organization, offering a new EEM product, and funding HERS organizations, to changing building codes, conducting studies, and working with the media, advertising, and educating the public.

Integrating the Infrastructure for HERS and EEMs into the Rest of the Housing Industry

The funding by the DOE, the five-state pilot project of EEMs by the FHA, and to some degree the evaluation reports by NREL played an important structuring role on the overall system-building effort during the 1990s. However, structuring does not mean successful coordination. By using successful corporation R&D projects as a standard of the amount of planning and coordination that is possible in pilot projects and studies, the lack of it in HERS-EEM pilot projects and the study is truly striking. The type of careful, efficient, and meticulous ratcheting up of a project that was seen in DuPont's development of Nylon is not seen here.

Planning the pilot projects and the study: There were two pilots that were very loosely coordinated. One was planned by the DOE to last 5 years from 1993 to 1997 that was on HERS and EEMs, and was to include a pilot study. The second pilot was by the FHA and was planned to last two years. On May 24, 1993, the FHA began this pilot project on its EEM product for *existing homes*. HERS organizations would certify that the homes met the FHA energy efficiency requirements for the EEM. It does not appear that the DOE had any extra money allocated to them by Congress for the pilot or for any study. However, within 2 years (by May 1995), the Assistant Secretary of Housing would make a decision of whether to implement a nation-wide program for *existing* and also for *new homes* (Farhar et al. 1997). All of this was either specifically directed or implied by EPAct.

FHA, NREL, and EERE made other important decisions about the pilot projects and the study that were not specified by EPAct. The FHA chose the pilot states of Vermont, Virginia, Arkansas, California, and Alaska for its two-year pilot because they already had an existing HERS program for a number of years. For its pilot study, the DOE chose to pursue a five-year pilot project and study, and it did end up offering funding to the same five states that participated in the FHA EEM pilot study. Also, it was decided that NREL would evaluate each of the states in the pilot project through interviews of the staff of HERS organizations and an analysis of data that the HERS organizations and NREL collected. (Also, Fannie Mae, Freddie Mac, and the Veterans Home Administration began offering EEMs, and NREL decided to include information about them in their study as well.)

However, there were serious problems with the design of the pilot projects and study, with its implementation, and with the broader system-building process that encompassed the pilot. The DOE pilot study was planned by NREL with the aid of a pilot study work group made up of HERS and EEM advocates from the HERS Council and elsewhere (Farhar, Collins, Walsh 1996; 1997). Broadly stated, the pilot projects and study were far too broad in scale and scope, and financial resources were not well allocated. There was relatively little coordination between the FHA and the DOE pilot and related matters. The pilot project by the FHA was to be conducted in too short of a time frame to collect the type of data that was needed, and data was to be put to uses that were not appropriate. These problems appear to have been due to a deficiency of capacities for strategic planning and coordination that showed in terms of resources being spread to thin, not enough time allocated to complete tasks in the pilot and studies, too broad of a focus, matching financial resources with needs, moving ahead to the next stage of system building before major problems were solved in a previous stage, and other ways.

In regard to the study design, these were the specific problems. *First*, EPAct mandated that the EEM pilot project be conducted in five different states, instead of a smaller more manageable single-state pilot and study. This greatly diluted the DOE money for program set up and evaluation. For example, HERS organizations did not have the financial resources to conduct the marketing they believed that needed to be done, nor to collect and manage the data on ratings performed and energy improvements that resulted. Not enough money was available for the evaluation stage. NREL's budget only allowed for a superficial analysis—not the detailed and methodologically rigorous evaluation that was needed.

Second, the pilot projects and study was on three different things, which was far too many for the budget and timeframe of the study. It was on the market feasibility of EEMs, feasibility of HERS ratings, and the linkage of the two. In actuality, EEMs and HERS ratings are very different products/services that each necessitated their own thorough pilot project and study, and further development before the market feasibility of actually linking them could be explored.

Third, the FHA EEM pilot study was to provide the Secretary of HUD with information to decide if the FHA should expand the availability of EEMs for both existing and new housing, although the pilot project was only on existing housing. These are two different housing markets with different buyers that purchase homes for different reasons, containing different technical issues, and involving different sets of housing professionals. The information collected by a study of existing housing simply cannot be expected to apply well to new housing.

Fourth, the FHA EEM pilot project was to be completed in two years, at which time the Assistant Secretary of Housing was to decide if EEMs should be offered nation wide. Two years was far too short a time frame to do the needed organization building, introduce new products and services to an unfamiliar market, and conduct a thorough analysis of the problems, solutions, and market potential.

There were other ways of structuring a pilot study, which would probably be common sense to most R&D professionals, that would likely have produced more useful information. These include 1) conducting a more rigorous evaluation of the market *before* spending the money to put EEMs and HERS in the field, 2) scaling back the pilot project and study into a single state, 3) narrowing the study to either just HERS or just EEMs, 4) using a longer time frame for the pilot project and study, and 5) using the money saved from the reduced scale and scope to assist a single state with organization building, data collection, and a more thorough evaluation.

A reasonable explanation of the structure of the DOE and HUD pilot can be given from the organizational structures responsible for strategic planning and coordination. The largest problem may have been the parochial and political interests of those who determined the design of the pilot project and study, which was to a large degree the United States Congress. These strategic planners were immersed in political routines that did not allow their isolation from the parochial interests of the very interest groups and government agencies who wanted funding for their own states and answers to their own pet questions. Although a single-state pilot on just one of either HERS or EEMs would have made more sense from an R&D perspective, a five-state pilot of both HERS and EEMs was able to please the political constituents in more states and the participant-advocates of both HERS and EEMs. Furthermore, the overly short two-year time frame coincided nicely with the two-year election cycle of Congress.

Problems with implementation: First, money from the DOE was not coordinated well enough to arrive in the pilot states when it was needed. It did not arrive until mid 1995, only a few months before the two-year pilot was to end. The DOE money was intended to help HERS providers with program development and data collection in preparation for the evaluation by NREL. Fortunately, a few of the HERS providers were able to obtain at least some alternative funding from SEOs, utilities, and other sources for these activities.

Second, when funding did arrive, millions of dollars in external funding was spent training thousands of raters even after it was fairly obvious that there was very little demand for ratings. Most raters did not have any business to apply their training to, and quickly moved on to other work.

Third, most of the HERS organizations did not have the capacity to collect and manage most of the data on HERS and EEMs that was needed for the pilot study. These capacities would have included routines for the collection and management of data regarding 1) the number of ratings conducted, 2) the use to which ratings were put (e.g. for EEMs), 3) the specific energy improvements that were made, and 4) the difference between predicted and actual energy savings. Much of this information was inherently difficult for most HERS providers to collect because it was the independent HERS raters who worked in the field that had contact with homes and homeowners over whom HERS providers had little control. Also, (5) no state had a set of routines to keep, collect, and manage information on the market value of homes that were rated. (6) Some HERS providers did not have complete information on their sources of funding (Farhar et al. 1996; 1997).

Fourth, lenders did not have a set of routines to collect and manage accurate data on the number of EEMs used around the nation. Using the FHA EEMs as an example, the FHA's on-line CHUMS database had serious data collection errors for EEMs, and was not trusted by the FHA, NREL, or HERS providers. However, CHUMS was the only mortgage data available in most cases.[89] Fannie Mae and Freddie Mac did not even attempt to earmark EEMs in their databases.

Fifth, CHUMS data was organized by "fiscal year" but the data collected by HERS organizations was typically by "calendar year." Even to the extent that the CHUMS data may have been accurate, it was impossible to draw meaningful conclusions about the number of ratings that resulted in EEMs.

Sixth, NREL wrote that it was not provided sufficient resources to collect the necessary data and conduct a thorough evaluation. They did not interview stakeholders such as lenders, realtors, builders, and appraisers, and consumers to explore their perceptions and experiences with EEMs. The interviews were only of HERS and EEM advocates and thus reflected only their perspectives.

Seventh, NREL did not complete their entire study until 2000 which was after most decisions had already made by the DOE about its future support of HERS and EEMs (Farhar et al. 1996; 1997; Fairey et al. 2000).

Eighth, NREL did not have the capacities to control and coordinate many key aspects of the pilots. They had no control over the HERS raters that had better access to information on how EEMs were used and over the secondary mortgage lenders who had the ability to collect accurate data on EEMs. Although this isolation of NREL from parochial interests of HERS organizations and stakeholders may have

[89] The CHUMS database had 1,435 EEMs recorded from the beginning of 1993 to the end of 1995 (which is a longer period than the actual pilot study), and achieved a market penetration of a modest 0.3%.

allowed a more objective evaluation, they could not structure the pilot and study to collect good data. This was similar to the problems that R&D laboratories had in the late 1800s. The early labs that conducted the most innovative and successful R&D projects were those that balanced their degree of isolation from production facilities, on one hand, and their integration with these facilities on the other.

The decision to go national: The five-state pilot project continued until October 6, 1995 and the Assistant Secretary for Housing, Nicolas P. Retsinas, decided to go national with the FHA EEMs (Retsinas 1995). However, this was *before* NREL published a single report on the pilot. NREL was still collecting data, and was one year from finishing even a preliminary report. The information upon which the Assistant Secretary made his decision is not known, nor are the criteria he used. However, given the difficulties that NREL had in collecting and analyzing data and the very short time frame, it seems very unlikely that HUD could have done substantially better with no extra money from Congress.

NREL published two preliminary studies. In October 1996, it released the a preliminary report *Case Studies of Energy Efficient Financing in the Original Five Pilot States, 1993-1996* (Farhar et al. 1996) and then in May 1997 it published *Linking Home Energy Rating Systems with Energy Efficiency Financing: Progress on National and State Programs* (Farhar et al. 1997). Then in year 2000, it produced two final reports: *National Status Report: Home Energy Rating systems and Energy Efficiency Mortgages* by Plympton (2000) and *Pilot States Program Report: Home Energy: Rating Systems and Energy-Efficient Mortgages* by Farhar (2000).

The evaluation of fit: The pilot study did generate some useful but usually quite vague information, and much of it was based on anecdotes or data with significant flaws. Briefly stated, it was learned that EEMs were a much more difficult mortgage product to sell than originally hoped. HERS providers had been depending on EEMs as the main source of demand for ratings. Some specifics are below.

First, HERS and EEM advocates learned that the benefits of EEMs were not as attractive to lenders as hoped. The extra money that could be loaned, perhaps $8,000, did not mean much additional benefit to lenders relative to the extra complexity and paperwork they perceived. Also, when substandard homes need energy improvements or borrowers had difficulty qualifying for mortgages, lenders had easier, more familiar ways to address these problems (Farhar et al 1997). However, no systematic attempt was made to understand what features in an EEM were the most important to lenders.

Second, efforts to market EEMs did not work well. The FHA mortgagee letter was almost useless, since brokers receive hundreds of such letters per year. Moreover, secondary mortgage lenders did not aggressively promote EEMs because their concern had not been addressed that the energy efficient technology would not save as much money as predicted, and energy efficiency would not have the market value in case of default. Also, brokers were concerned that the secondary lenders might not actually purchase EEMs (Farhar et al 1997). Mass advertising generated demand, but required large subsidies.[90] No attempt was made to actually study the market—to understand who the market was, what the market wanted, and how to communicate with it.

Third, better EEM products *were needed* that would be more attractive to lenders and borrowers, including higher loan limits, reduced interest rates, reduced closing fees, no additional down payment, no additional mortgage insurance, and/or additional incentives. However, there was no real attempt to figure out which characteristics were the most important to lenders and borrowers.

Fourth, HERS providers had not yet found a successful business model to generate a market value for ratings and lead to energy improvements being made. For every pilot state, there were too many raters and not enough customers (Farhar et al 1996; 1997). Also, a large percentage of the ratings for most HERS providers did not result in energy improvements. For example, the California Home Energy Efficiency Rating System (CHEERS) conducted over 17,000 ratings from 1993 to 1995, but only a small percentage (likely single digits) of them resulted in EEMs or other improved energy efficiency (Farhar et al 1997). People who received free ratings often had no intention or ability to increase energy efficiency.

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90 ERH-CO discontinued its radio advertisements, but the expense could not be justified without large subsides (interviews with staff from ERH-CO in 2000). The V-HERO increased their number of ratings from 250 in CY 1994 to 7,345 in CY 1995. However, it took a large advertising budget for ads on CBS Good Morning America, cable TV, and radio in the state of Virginia. With advertising cost at perhaps on hundred dollars or more per EEM, this would not have been possible without heavy subsidization. HERS providers only made between $15 and $30 for each rating they processed (Farhar et al. 1997). Indeed, V-HERO reported the higher operating cost per rating than any other HERS program. Also, ERH-VT found that mass advertising was not cost effective (Walsh 1997b; interview with V-HERO in 2000).

There was a *fifth*. Although the NREL reports gave very little attention to it, the 1997 preliminary clearly implied that some individuals were in fact making EEMs work. These individuals and organizations of a small network of HERS and EEMs system builders in the Sacramento and the Bay area of California were making a good profit from EEMs with little or no subsidies. About 80% of their ratings resulted in EEMs for existing homes and installation of energy efficiency retrofits. This success was due to referrals from allied businesses that ran EEM facilitation services. These facilitators would aggressively network with mortgage brokers and loan officers asking for referrals to homebuyers that would be good candidates for EEMs. The facilitators acted as general contractors who would then arrange for ratings, find contractors to install retrofits, complete the extra paperwork for the loan officer, and ensure that everything happened smoothly and on schedule, which removed most of the complexity and risk from EEMs for existing homes (Collins 1997b).

However, the NREL report gave very little attention to Energy Plus and the EEM facilitators. Even though in a small area (approximately that of Sacramento), they had rated 190 homes that resulted in EEMs from 1994 to 1995 without any subsidies. This was more than any other pilot state except for California itself where facilitators accounted for 18% of the EEMs during 1994 to 1995. By many measures, Energy Plus had been the most successful HERS provider in the country, which will be discussed in the next chapter. The reason for so little attention by NREL might have been that neither these particular HERS providers nor the EEM facilitators were being funded by the DOE.

By the end of the 1990s, participant-advocates of HERS and EEMs were experimenting with different ways to better integrate the organizational and institutional infrastructure for HERS and EEMs into the existing housing industry. This remained a very decentralized, network approach to system building with very little resources being deployed on any one effort, and it appears that typically there was no thorough or sustained investigation on what works and what does not, why or why not, and how to make them work better. These include the following. *First,* the participant-advocates and stakeholders pursued changes in HERS and EEMs to better integrate these with the housing industry. As noted, the HERS Council and later RESNET were working on national guidelines for HERS systems to both standardize them and improve their accuracy and reliability. Also, various mortgage bankers were experimenting with different EEM products, such as Fannie Mae who made repeated attempts to find an EEM product that sells. Also, in the late 1990s, some of the conventional (non-government) mortgage lenders would offer EEMs, which was an important development because there was no mortgage limit on them. In theory, it dramatically increased the potential market for EEMs to beyond that of first-time and low-income homebuyers.

Second, HERS providers switched from focusing on existing construction and EEMs to that of rating new construction as a strategy to generate demand for ratings. Increasingly through the latter half of the 1990s, most HERS providers and raters were giving up on both existing construction and EEMs. Although it could be argued that a serious, well-thought out, sufficiently funded attempt to make EEMs work was never made, they gradually turned to the strategy of rating new construction and labeling new homes as energy efficient to create a demand for energy efficiency in the new housing market. If a newly constructed home achieved above a certain score on a HERS rating, they would receive a label for that home, marketing material, and legitimacy to the claim that the construction was truly energy efficient. Different HERS programs used different labels and brand names.

Third, HERS providers and RESNET worked to link scores on HERS ratings to energy code compliance, and convinced some jurisdictions to allow ratings to satisfy code requirements. This allowed builders usually to receive a reduction on building permit fees as well as being able to label homes energy efficient. Also, ratings allowed more design flexibility than if builders achieved compliance through old-fashioned check lists (Colorado Housing and Finance Authority 1998).

Fourth, HERS providers worked to tie HERS ratings to participation in other energy efficiency programs such as utility DSM and SEO programs. Also, green builders used HERS ratings for some of their green building standards. *Fifth*, HERS providers tried to have the results of HERS ratings included in multiple listing services (MLS), but realtors have been resistant to such efforts (for example see Walsh 1997).

Conclusion

By 2000, limited progress had been made to integrate HERS ratings and EEMs into the day-to-day activities of the residential housing industry. The HERS industry was still struggling, and many HERS professionals were growing increasingly nervous about how they were going to keep their doors open. NREL predicted that "considerable financial subsidies" would be needed "over fairly long periods of time" for most HERS providers (Farhar et al. 1996, 20). However, the DOE soon terminated its funding for both the HERS Council and HERS providers. HERS organizations were being forced to quickly become much more self-sufficient, or close their doors. Some of the earlier leaders among the participant-advocates did in fact "call it quits" at the end of the 1990s, including the HERS Council.

Comment [KM1]: Any idea why?

The meager organizational capacities of HERS and EEM participant-advocates for system building in the 1990s were sufficient to reach consensus and establish the basic institutional and organizational infrastructure. This had not been too difficult. There had been a long standing concern about the quality of residential construction by broad cross sections of society including parts of the building industry, the Business Roundtable, consumer groups, and government dating back almost a century to the early proponents of the building industry. HERS and EEMs were inexpensive, voluntary, market-based solutions that had the potential to increase the quality of the housing stock. This was appealing to many and fit well with the broad-based, consensus approach that participant-advocates took toward system building. With the help of the federal government, the organizational capacities needed by HERS and EEM advocates to build this basic infrastructure were minimum—not much more than a simple set of organizational routines to deliberate and reach consensus through 10 meetings of the National Collaborative, additional meetings by the HERS Council, and some grassroots lobbying of the DOE, HUD, and Congress. Clearly, there were advantages to this decentralized approach. It allowed HERS and EEM advocates access to more financial resources and voluntary help than otherwise possible. It also generated a wealth of ideas about how to make EEMs and HERS succeed (National Renewable Energy Laboratory 1992).

However, it would take greater and more sophisticated organizational capacities to integrate this organizational and institutional infrastructure for HERS and EEMs into the day-to-day activities of the residential housing industry. On the large scale, the five-state pilot study was intended to help with that process of integration—to help HERS organizations gain an understanding of what worked and what did not. However, setting up effective pilot projects and studies required organizational capacities for strategic planning and evaluation and for coordination that did not exist or at minimum were not mobilized by this fragmented decentralized network of system builders.

This pilot project and study makes a dramatic contrast to the extremely well-planned and implemented R&D project conducted by DuPont 70 years ago, which is now routine among research oriented corporate organizations. After considerable background research, DuPont undertook the project with unwavering commitment and focused like a laser beam on developing nylon for a very narrow, pragmatically chosen market. Each stage of the R&D project was planned, and systems arrangements were efficiently and meticulously ratcheted up after the completion of each of these stages. In five short years they went from basic science to a new set of complex system arrangements that supported the market success of a rather radical new technology.

Chapter 10: Integrating Home Energy Ratings and Energy Efficient Mortgages into the Residential Housing System

The focus of the previous chapter was on the organizational capabilities of HERS and EEM participant-advocates to build a nation-wide, organizational and institutional infrastructure for the use of EEMs and HERS and also to integrate that infrastructure into the day-to-day activities of the housing industry on a national scale. This chapter takes a more micro view of that process. More specifically, it compares and contrasts two different approaches to integrating EEMs for existing homes into the daily activities of the housing industry at the community level, and also two different approaches to integrating HERS ratings into the daily activities of the industry, also at the more local level.

In both cases, the participant-advocates that took the approach of internalizing activities of the larger system into their own organization were the most successful. In both cases, the sets of activities that they internalized were actually parts of the system that they had created at an earlier time. Just as in Chapter 2, some products and services cannot be dependably bought and sold on the market, and in such cases the only feasible option that system builders often have is to internalize those activities so as to control and coordinate them with other activities.

Integrating EEMs into Day-to-Day Routines of the Housing Industry

It was mentioned that advocates of EEMs developed two different organizational approaches toward system building to integrate the use of EEMs for existing homes into the housing industry. The first approach is where HERS providers relied heavily on incentives and education. Specifically, they solicited subsidies to offer ratings at below cost, advertised EEMs to homebuyers and stakeholders, and trained stakeholders about HERS and EEMs. These HERS providers have historically been non-profits and government offices/programs. The second is a market-driven approach typically used by for-profit firms that controls parts of the mortgage process by internalizing them into their firms. They establish one-on-one relationships with lenders to obtain referrals to homebuyers and to then take a direct role in facilitating the completion of EEMs by coordinating the various actors and activities involved.

The approach of subsidizing, training, and advertising was mostly to educate housing professionals and then hope they take the initiative to use EEMs. In contrast, EEM facilitators would themselves take the initiative to build the organizational routines that were needed to directly control and coordinate the EEM process to ensure that these mortgages were quickly, efficiently, and successfully brought to completion. This was the difference between, on one hand, telling the housing industry it should use EEMs, and, on the other hand, actually taking steps to build the day-to-day organizational routines to use EEMs. The soliciting of subsidies, advertising, and training approach have been more common than facilitating EEMs. There was at least one HERS organization using the approach of subsidizing, training, and advertising in most of the lower 48 states by 1999. However, this approach usually failed to make a noticeable impact on the local and national markets (Plympton 2000) nor did it create a set of organizational routines that could survive without subsidies. Although far less common, the approach of facilitating EEMs has enjoyed local successes without direct subsidies.

To appreciate the different successes of these two approaches, it is important to understand that EEMs for existing homes are more complex and time intensive than most mortgages. Unless these complexities and time-sensitive details are well managed such as by facilitators, a deficiency of information, control, and coordination will disrupt the EEM process.

Deficiency of Routines for Information, Control, and Coordination

The most common complaints about EEMs from loan officers, realtors, and homeowners are that these mortgages are too complex, time-consuming, and have too many hassles. This perception arises from the additional tasks associated with EEMs. However, that alone does not explain the matter. The overall process of mortgage financing is considerably more involved and complex than the additional tasks and complexities that are needed to complete EEMs. Of course, most of the complexity of conventional mortgages are “behind the scenes” in the offices of mortgage brokers, underwriters, loan processors, secondary mortgage lenders, and the firms that manage the global financial system. Why is this complexity for conventional mortgages accepted, and the new complexity for EEMs not?

Although home buying is arduous, it is usually considered manageable because the hundreds of involved tasks have been institutionalized into routines carried out by real estate professionals. Activities that would otherwise be immensely complex have been reduced to sets of small details in their work schedule. Taking care of hassles has become the specialty of workers who engage them without a second thought, and delays have become the accepted length of time to accomplish the process.

If EEMs for existing homes are to be widely used, the tasks to complete EEMs (Table 10-1) need to be institutionalized into a set of routines to guide the flow of information and to control and coordinate the activities of housing professionals. The lack of these routines has been a *serious deficiency* for the wide spread use of EEMs in the existing sociotechnical systems, and hence the title of this section.

When EEMs are in fact used, it appears to be as non-routine behavior and as individual routines unsupported by a broader organization. Well-developed organizational routines are usually missing. The lion's share of the activities in Table 10-1 usually default to homebuyers who have no experience at coordinating housing professionals, conveying technical information to housing professionals, and the use of paperwork and specialized terms in mortgage finance and energy efficiency. Lenders and realtors will also often find these activities problematic. Although they have more appropriate background knowledge than most homebuyers, most of them are not highly experienced in the nuances of EEMs, completing them has not developed into a comfortable routine, and they tend to view them as extra hassle.

The activities that are shaded in Table 10-1 are particular to the completion of EEMs and are not part of a conventional mortgage process. These additional activities sum to approximately nine or more extra tasks for homebuyers, six or more for lenders, and two for HERS raters that historically have not been part of the process of financing and selling homes. These can range from 15 minutes to perhaps 3 hours apiece, and must be completed in an efficient, timely, accurate manner if the mortgage process is to proceed on schedule and meet everyone's contractual obligations. Reports from the field suggest these tasks are often not completed on time, completed well, or completed at all, resulting in unwelcome hassles, liabilities, and expenses for busy housing professionals and anxious sellers and buyers.

Table 10-1. The energy efficient mortgage process for existing homes: Activities involved finance energy improvements in existing housing using EEMs. The extra activities that are particular to an EEM, and not usually part of a mortgage process, are shaded.

	The participant	The activity
1.	**Homebuyer**	Tells lender that they want an EEM.
2.	**Homebuyer**	A HERS rater is contacted and a rating is scheduled on the home.
3.	**HERS rater**	Conducts a HERS rating, completes a data sheet, and generates a HERS report and other documentation for the lender.
4.	**Homebuyer**	Decide what energy upgrades to finance through the EEM.
5.	**Homebuyer and sometimes the lender**	Finds qualified contractor(s): checks with past contractors, yellow pages, and homeowners for leads.
6.	**Homebuyer**	Contact and solicit the interest of up to 3 contractors for each of perhaps 3 different retrofit tasks.
7.	**Homebuyer**	Arrange for up to 9 different contractors to make a site visit.
8.	**Homebuyer or realtor**	Answer contractors' questions and arrange a site visit if needed.
9.	**Contractors**	Inspect the job site.
10.	**Contractors**	Place bid.
11.	**Homebuyer**	Collect bids, choose retrofits to be completed, and select contractor. (If all bids are higher than the financed amount, the homebuyer has the option of buying down the mortgage or soliciting more bids.)
12.	**Homebuyer**	Contact the winning contractor(s).
13.	**Homebuyer**	Prepare contracts for one to three contractors.
14.	**HERS rater**	Complete paperwork for underwriting and appraisal adjustments.
15.	**Lender**	Completes the loan request and includes allowable improvement costs into the mortgage, and sends the mortgage application to loan processing.
16.	**Lender**	Loan is processed, which takes about one week.
17.	**Lender**	Prepares an escrow account and agreement.
18.	**Lender and homebuyer**	Bank closing: Homebuyer meets with lender for final signatures and to place the upgrade funds into escrow.
19.	**Homebuyer**	Real-estate closing: Buyer meets with seller and real estate attorney to close the contract, and to pay the seller.
20.	**Homebuyer**	Seller moves out, and the buyer moves in.
21.	**Homebuyer**	Home buyer and contractor(s) negotiate the time of the work.
22.	**Lender**	The mortgage is sold to a secondary mortgage lender.
23.	**Contractor(s)**	Completes retrofit(s) within mandatory time (90 to 120 days).
24.	**Lender**	Lender calls homeowner to see if work is completed.
25.	**Lender**	Lender selects inspector or HERS rater to verify installation.
26.	**HERS rater or inspector**	The retrofit is inspected to ensure adequate installation.
27.	**Lender**	Lender authorizes escrow to release money to contractor(s).
28.	**Lender**	Lender sends certification of completion and notification of a closed escrow account to the secondary mortgage market.
29.	**Lender**	Lender closes loan file.

(Sources: Building Performance Contractors 2003, Northeast Home Energy Rating System Alliance 2003, Federal Energy TEEM 2002, and interviews with staff of ERH-VT).

I want to define the three terms that I used—non-routine behavior, individual routines, and organizational routines. All of these have implications for system building although the latter is by far the most important. N*on-routine behavior* is behavior that occurs once or occasionally, but not enough to develop a set of practical knowledge, skills, and network contacts that are retained from one occurrence of the behavior to the next. When the use of EEMs is non-routine behavior, it is problematic to the successful, widespread use of these mortgages for two reasons. First, the individuals engaging in non-routine use of EEMs typically do not have the practical experience to smoothly and quickly bring EEMs to successful completion, which seems to frustrate all participants and reduces the chance that they will use EEMs again. Also, by definition, the non-routine use of EEMs implies that EEMs might not ever be used again by that individual. There is nothing systematic about non-routine behavior, and its contribution to system building is usually minimal and can even harm the effort if problems associated with it frustrate the involved participants. Nevertheless, if enough individuals engage in non-routine behavior it can aggregate into a set of effects that can positively and/or negatively affect a system-building effort.

Individual routines are behaviors that occur with regularity, and there is enough repetition to develop a set of practical knowledge, skills, and network contacts that are retained from one occurrence to the next. However, the routine is not integrated into a larger organizational structure. When EEMs are used through individual routines, the completion of it is likely to occur with proficiency, although the individual may not have full access to the resources of a larger organization. The largest problem is that when the particular individuals retire, quit, or die, there will likely be no one else to take over that routine. These routines do assist the system building process, but not as much as if fully integrated into an organizational structure that will survive beyond the tenure of a single individual at an organization.

Organizational routines refer to routines that are part of a larger organizational structure. This typically gives the individuals performing these routines access to organizational resources, technology, network contacts, and human resources that they would not otherwise have. Moreover, carrying out organizational routines is part of someone's defined role or job, and when they leave that organization someone else is likely to be trained to a similar level of proficiency to replace them in that routine. Establishing organizational routines is fundamental to successful system building.

The Two Approaches to EEMs by HERS Organizations

The *approach of subsidizing, training, and advertising* was a strategy to convince and teach others to use EEMs by subsidizing HERS organizations to offer HERS ratings below market costs, use of advertising directed at homeowners and stakeholders, and to educate them about EEMs. Most often, these advocates of EEMs use one-time training sessions of lenders and members of other industry stakeholder groups to educate them about the benefits of EEMs and how to use them. HERS organizations hoped that it would generate a large amount of demand for HERS ratings. Furthermore, it was hoped that once stakeholders and homeowners knew about EEMs, they would use them on their own initiative. The market would then be permanently transformed, and subsidies could be removed. This approach has strongly resembled the traditional DSM programs in that it has relied on subsidizes, advertising, and training. It also resembles traditional DSM programs in that these HERS organizations did not participate in the core processes of the residential housing industry—they mainly operated from the periphery conducting education, advertising, and offering incentives.

The DOE, SEOs, utilities, and utility consortiums provided over $15.4 million to HERS providers and HERS software developers in the 1990s to jump start HERS and EEM activity. A large share of the money went to the HERS organizations that participated in the DOE pilot project and study from 1993 to 1998 that was previously mentioned. In the mid to late 1990s, dozens of other HERS providers emerged around the country and adopted this approach of relying on subsidies, advertising, and marketing. These other HERS providers typically received funding from utilities, state governments, and SEOs.

Some of the HERS providers that adopted this approach have been Virginia Home Energy Rating Organization (V-HERO), Energy Rated Homes of Arkansas (ERH-ARK), Energy Rated Homes of Vermont (ERH-VT), and the California Home Energy Efficiency Rating System (CHEERS). All of these were EEM/HERS pilot states in 1993 to 1995. Then, in 1995, Energy Rated Homes of Colorado (ERH-

CO) and Energy Rated Homes of Mississippi (ERH-MS) also joined the DOE HERS pilot program. In addition to HERS providers, the HERS software developers of ERHA and N-HERO also used this approach to promote EEMs, and RESNET did as well.

However, this approach has not worked well to create durable system arrangements to complete EEMs. It was unable to establish a sustained set of market-driven, organizational routines. In the latter half of the 1990s, HERS organizations realized that EEMs were not as popular with lenders as they had hoped, and would not provide a substantial source of demand for ratings in the foreseeable future. For lenders and realtors, if EEMs for existing homes were too unusual and complex of a mortgage product, then they had many other simpler mortgage products to offer. Realtors in particular perceived it as adding to the risk that real-estate transactions might fall apart.

The *approach of EEM facilitation* has been more hands-on. Instead of merely advocating the use of EEMs to homebuyers and members of the housing industry, these individuals *have* adopted the participant-advocate approach described in Chapter 1. Instead of advocating from the periphery of the industry, EEM facilitators have become a central participant in day-to-day activities of the residential housing industry at the community level. These facilitators are also referred to as “EEM service companies.” They focused entirely on the use of EEMs for *existing housing* to finance energy improvements through the mortgage process. With few if any subsidies, the individuals that facilitated EEMs have often made a good living for themselves and given business to HERS raters and subcontractors that specialize in retrofitting existing homes with energy efficient technology.

EEM facilitation has only been successfully conducted by a small group of for-profit firms in California and a non-profit in Vermont. The primary California firms have been the Energy Efficient Mortgage Service Company (which became EEMs, Inc.), Federal Energy Services (which became the Federal Energy TEEM), H&L Energy Services, and Mortgage Training Services (Collins 1997b). The single organization in Vermont that did EEM facilitation has been ERH-VT, which switched in 1997 to facilitating EEMs from that of the approach of subsidies, advertising, and training. (A number of other organizations have attempted to facilitate EEMs in California, New York, Idaho, and Massachusetts, but apparently have not managed to create a sustained set of routines to facilitate the use of EEMs).

EEM facilitators keep in weekly or even daily contact with individual mortgage brokers and loan officers to obtain referrals on homebuyers who are good candidates for an EEM, speak to the homebuyers about using an EEM, and then enter into an agreement with homebuyers to facilitate the EEM process in a timely, efficient fashion so as to not delay the closing. The facilitation of the EEM process involves arranging for a HERS rating, identifying cost-effective energy improvements, helping homebuyers choose from this set of improvements, sending bid sheets to contractors, assisting with loan paperwork, then arranging with the new homeowner for all the contractors to have access to the home at the same time to complete their retrofits, arranging for a HERS rater to inspect the construction work and conduct a post rating, completing more paperwork for the lender, and arranging for the funds to be paid from escrow to the contractors and the facilitators themselves.

The Approach of Subsidies, Advertising, and Training: Organizational Capacities

HERS providers are primarily organized around running and managing rating systems—processing ratings using HERS software, training raters, performing quality control, and keeping an existing number of customers. This is where a substantial if not a large majority of their organizational capacities have been focused. In other words, it has been focused on the less glorious task of the running and managing the day-to-day (i.e. operational) aspects of the existing system arrangements. However, here we will focus specifically on describing their organizational capacities (and specific routines) for system building for one very specific goal—to integrate EEMs into the day-to-day activities of the housing industry.[91] Typically, HERS providers have been small organizations with one to ten employees, which impose structural limits on their organizational capacities. When there has been more than one staff person, the model has been for the executive director to directly supervise and coordinate the activities of all administrative and program staff (conclusion reached based on Farhar et al. 1997; also confirmed through

[91] To promote EEMs, HERS organizations sometimes worked in coalition with state agencies such CHEERS with

interviews with HERS organizations in 2004). It is impossible for small organizations such as this to have all the in-house organizational routines for a full set of capacities for system building.

Strategic planning and evaluation: By default or intention, much or all of the major responsibilities for strategic planning commonly fall upon the executive directors of small organizations, which have the major implication of requiring them to balance their time between strategic and day-to-day (i.e. operational) management. As discussed in Chapter 4, a lack of separation between strategic and operational management was shown to significantly impair the strategic capacity of organizations. It often does not allow enough time and resources to be devoted to strategic matters, and it creates a situation where the identity, rewards, and responsibilities of top management are heavily invested in the status quo of the organization's existing day-to-day routines. This is not a structure for change.

Capacity to generate financial resources that can be flexibly used: In the 1990s, the budgets of young HERS organizations to promote EEMs were often fairly large, although apparently somewhat constrained. The four initial pilot states that are included in this case study (which excludes Alaska) and two pilot states that were added in 1996 had more than 15.4 million dollars in start up and operating funds through 1998. On average this was over one-half million dollars per year per state in the 1990s.

Table 10-2 shows the sources of 15.4 million plus dollars for the HERS organizations (which were mostly HERS providers[92]) in the seven pilot states from 1993 to 1998 (and prior to 1993 for some), which includes funding from various federal, state, and private sources. Also, states including Vermont and Arkansas received funding prior to the years in Table 10-2 that was probably in excess of several million dollars combined. In addition to the seven pilot states in the table, the DOE funded HERS programs in Delaware, Florida, Idaho, Iowa, Kansas, Kentucky, Michigan, Nebraska, Ohio, Washington, and Wisconsin ranging from $10,000 to $50,000 per year in 1998 and 1999. Furthermore, states, non-profits, and utilities provided additional funding to these eleven HERS providers.

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the California Energy Commission.

[92] In California and Alaska, more than one organization received funding to promote HERS and EEMs. In California, CHEERS received a large majority of the funding and the California Energy Commission received the rest.

Table 10-2 Funding for HERS and EEMs: Funding volumes in U.S. dollars for the major rating and EEM activities that were conducted by HERS organizations and others in the HERS/EEM pilot states, 1993-1998.*

State/ Years	DOE/ NREL	SEO	Utilities	State	Ratings, Dues, etc./ In-house	Other	Total Funds	Percent DOE
Arkansas								
1993-95	140,000	170,500	0	0	0	68,300	378,800	37.0%
1996	91,709	0	31,000	0	19,626	789	143,124	64.1%
1997	148,291	0	3,900	0	3,625	9,717	165,533	89.6%
1998	132,315	0	0	0	5,548	840	138,703	95.4%
California**								
1993-95	270,000	200,000	1,742,900	165,000	553,600	228,000	2,994,500	9.0%
1996	232,625	114,525	500,000	0	377,580	0	1,224,730	19.0%
1997	318,000	0	400,000	0	494,583	0	1,212,583	26.2%
1998	238,852	0	300,000	0	958,170	0	1,497,022	16.0%
Vermont								
1993-95	140,000	34,250	0	30,900	375,200	13,700	683,150	20.5%
1996	117,750	10,000	0	41,796	152,794	34,219	314,763	37.4%
1997	116,661	0	0	37,619	196,883	5,299	318,843	36.6%
1998	123,426	0	0	38,492	121,633	21,885	266,944	46.2%
Virginia								
prior	0	0	0	200,000	0	0	200,000	0.0%
1992	0	75,000	0		0	0	75,000	0.0%
1993-95	200,000	225,000	100,000	70,000	45,000	100,000	740,000	27.0%
1996	144,084	0	32,500	0	7,000	0	183,584	78.5%
1997	207,135	0	0	0	7,362	0	214,497	96.6%
1998	227,831	0	0		18,809	116,067	362,707	62.8%
Mississippi								
1993-95	-	-	-	-	-	-		-
1996	28,001	74,624	-	0	3,544	9,932	116,101	24.1%
1997	124,631	0	-	0	3,603	156	128,390	97.1%
1998	146,951	31,333	-	0	2,587	1,229	182,100	80.7%
Colorado								
1993-95	0	418,000	44,000	0	4,000	-	466,000	0.0%
1996	197,000	593,000	82,000	0	18,000	-	890,000	22.1%
1997	95,000	1,048,000	90,000	0	36,000	-	1,269,000	7.5%
1998	100,000	1,000,000	80,000	0	55,000	-	1,235,000	8.1%
	3,540,262	**3,994,232**	**3,406,300**	**618,807**	**3,460,147**	**608,504**	**15,628,252**	**22.08%**

**Adapted from Farhar (2000) and Farhar et al. (1997). HUD ran a pilot from 1993 to 1995. DOE ran a pilot from 1993 to 1998, but did not allocate actual money until 1995.

* Funding in California for HERS organizations as well as other organizations in the state working on HERS and EEMs. See Farhar (2000) for more details about funding.

However, HERS organizations lack some flexibility on how funding could be used for system building. Only 22.5%[93] of total funding came from self-earnings (dues, ratings, and consulting fees) that could be spent without constraints. The other 78% often came with constraints on how it could be used, such as for advertising, training, or in-house data collection and management. This was from diverse external sources including the DOE, NREL, SEOs, utilities and utilities consortiums, and state legislatures and agencies. These funding sources usually place stipulations how their funding is to be spent, although details about those constraints were not found.

The constraints placed on how grant money was to be used were likely not always heavy handed or intended to be a hindrance. Influence can be subtle. As DiMaggio and Powell (1983) and others have commented, being heavily dependent on other organizations for financial resources can subtly realign the views and strategies of a dependent organization to that of the funding organization. Further, even when grant-giving organizations want to be responsive to the needs of their recipients, it can be difficult. Funding criteria and levels are previously decided by administrative personnel, boards of directors, lobbyists, and/or legislative bodies often years before money is given to recipient organizations. This can make it almost impossible for donor organizations to meet the needs of recipient organizations in a timely manner as new problems, needs, and opportunities arise.

Organizational capacities for *information*, *control*, and *coordination* were seriously deficient for HERS organizations. HERS organizations had a rather easy time setting up routines to locate *information* about some aspects of the residential housing industry, but had a more difficult time obtaining other information that was important for system building. To market their trainings to the housing industry, they needed to obtain lists of lenders, realtors, appraisers, and contractors. Such information was readily available in the phone book or in other public listings, and it was easy to assign administrative staff to periodically update their internal lists of housing professionals. Such routines were to manage and control information that was already publicly available.

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[93] This percentage was calculated from dividing “ratings, dues, etc/in-house” by “total funds.”

However, HERS organizations had a more difficult time identifying homebuyers who were candidates for EEMs—information that was not publicly available. Except for using expensive mass media to reach homebuyers, HERS organizations had little choice but to rely on bankers and realtors to identify candidates and promote EEMs to homebuyers. Furthermore, in the early 1990s few or no market studies had been conducted on EEMs and HERS and the best way to package them (Farhar and Eckert 1993), and since then only very limited market studies have been conducted (see Lee et al. 2000).

Capacity to control: HERS providers did *not* have much control over stakeholders and homeowners to use EEMs. Their only real means was persuasion and access to information about how to use EEMs, benefits, and incentives. Specifically, they used training sessions and advertisements. From approximately 1993 to 1998, seven HERS organizations directly or indirectly trained almost 27,500 realtors, lenders, appraisers, and builders/contractors as shown in Table 10-3. Most HERS organizations in this table were part of the DOE pilot study. Training has also occurred beyond 1998 in some states.

Although this is a substantial number of housing professionals in absolute terms, it was small relative to the number of professionals in their service areas. Table 10-4 lists the approximate number of total housing professionals for the states where HERS were the most active. These relatively small numbers are effectively even smaller because the high turnover of housing professionals (often a year or two, see Bureau of Labor Statistics 2004; Farhar et al. 1997) reduces the number of trained realtors, real estate brokers, loan officers, mortgage brokers, and appraisers that are available at any particular time.

HERS providers were able to train the number of housing professionals that it did because of well-developed routines to efficiently gain access and transfer information to these professionals. They invested in training materials (handouts, slides, PowerPoint presentations, and testing materials), networks with housing professionals, and hired training specialists. The trainings were a routine activity for HERS providers. They held trainings ranging from one-hour sessions at annual trade conferences, to three-hour continuing education classes required for bankers and realtors to keep their licenses, to

Table 10-3. Number of housing professionals trained: These trainings were conducted in the HERS/EEM Pilot States from 1993 to 1998.

	Real-estate Agents	Lenders	Appraisers	Builders/ Contractors
Arkansas				
1993-1998	1,481	505	152	195
California				
1993-1995	2,650	450	29	1,685
1996-1998	5,614		0	0
Colorado				
1993-1998	1,002	546	206	72
Mississippi				
1993-1998	197	112	61	448
Vermont				
prior	560	112	252	0
1993-1998	289	278	0	0
Virginia				
1993-1998	7,038	1,910	73	605

Adapted from tables in Farhar (2000), Walsh (1997b), Collins (1997a), and Collins (1997b).

Table 10-4 Estimated number of housing professionals in pilot states: These estimates are for the period from 1993 to 1998.

					Specialty Trades Contractors in the Residential Housing Industry		
	Real-Estate Agents	Lenders	Appraisers	Residential Builders	Plumbing Heating and AC	Masonry Drywall Insulation and Tile	Carpentry and Floors
Arkansas	--	--	--	5,477***	2,480***	2,687***	6,768***
California	98,000*	70,000**	14,000**	45,318***	17,378***	14,518***	29,005***
Colorado	--	--	--	10,459***	3,356***	3,656***	10,451***
Mississippi	--	--	--	4,381***	2,078***	1,898***	5,497***
Vermont	--	--	--	2,035***	652***	502***	2736***
Virginia	24,000*	--	2,600**	12,215***	4,829***	4,948***	10,887***

Source: Walsh (1997b), Collins (1997a), and Collins (1997b), and also U.S. Census Bureau (1999d, 1999e, 1999f, and 1999g).

* For year 1995.
** For year 1993.
*** For year 1997.

sections in week-long classes for basic licensing requirements.[94] Some states have had several hundred thousands of dollars allocated to them for trainings in some years (Farhar et al. 1992; Farhar 2000). Interviews with HERS organizations suggested that the continuing education classes provided the most frequent and dependable access to housing professionals to convey information about EEMs and HERS.

These trainings included basic or advanced information on energy efficiency. This included energy efficient building technology and dollar savings from the technology, a description of HERS ratings, how to get a HERS rating and what was involved, the benefits of a HERS rating for homeowners and housing professionals, information about EEMs, their benefits, and how to complete an EEM.

Training sessions were geared toward specific professionals. If lenders were the trainees, the benefits of EEMs to the lenders were stressed. These included that EEMs could be used to . . .

- qualify buyers for a mortgage that they might not otherwise qualify,
- finance the repair of defective homes that would otherwise not be very sellable, such as through replacing an old furnace or adding more insulation and weatherization, and
- make larger loans with no extra risk.

The details of how to originate, underwrite, process, and close an EEM was also explained to loan officers and mortgage brokers, and key issues where how to . . .

- convince homeowners to get an EEM,
- arrange for a HERS rating,
- include the value of energy efficiency into the value of a home,
- add energy savings into the PITI equation of the underwriting process, and
- use an escrow account to hold the funds for energy efficient improvements.

If the audience was realtors, the emphasis was on the ability of EEMs to qualify buyers that may not otherwise qualify for a mortgage and to finance the repairs of homes that were below standard and otherwise difficult to sell. If the trainees were mainly appraisers, an emphasis was placed on accepted

[94] In states such as California, the SEO contracted with stakeholder groups to train their own group's members as a

methods to place a value on energy efficiency.

If the trainings were for builders and contractors, the emphasis would be on topics such as . . .

- building homes that are energy efficient,
- marketing energy efficiency to home buyers,
- financing the extra expense of energy efficient homes with EEMs,
  qualifying homebuyers through EEMs, and
- convincing homebuyers to use an EEM.

Also, it was stressed to builders that energy efficient homes had several advantages such as . .

- a higher quality home that was more comfortable and affordable,
- reducing call backs and warranty work, and
- a way to differentiate a product line from the competition and close deals.

As mentioned, most HERS organizations in the pilot states used advertising to inform homebuyers about EEMs. This included pamphlets, direct mail, inserts in utility bills, earned media, and ads in newspapers, magazines, and real estate guides. They also occasionally used radio and television advertisements. Some states had a few hundred thousand dollars in their advertising budget during some years (Farhar et al. 1997). Some states found that target advertising such as brochures in real estate racks was the most effective and cost efficient way to reach homebuyers (Walsh 1997b; Farhar 1997a).

Also, most HERS providers helped their HERS raters offer ratings at a reduced cost as a *financial incentive*. CHEERS provided 8,300 ratings at no charge (Collins 1997b) through subsidies, and ERH-VT provided 704 ratings from 1987 to 1989 Walsh (1997b). It was estimated by Edmunds (1996) that "Consumers have typically paid between $50 to $250 for a HERS rating" while it costs "about $680" to conduct each rating. A few HERS providers, such as ERH-CO, had arrangements to offer EEMs with a reduced interest rate (Colorado Housing and Finance Authority 1998). HERS providers have reported that these subsidies helped to generate business, but were quite expensive and not sustainable.

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way to gain access to housing professionals via a trusted source of information.

Rebecca Vories, a consultant on home energy rating systems (HERS) with Infinite Energy "They've proved, as others have, that if you give away free ratings and make a big splash, you will get a good response," says Vories. "But it remains to be seen whether people are willing to pay for ratings themselves" (Rieger 1993).

The Failure to Build Organizational Routines for the Completion of EEMs

Most of the evidence suggests that the approach of subsidizing, advertising, and training was not able to integrate the use of EEMs into the day-to-day activities of the housing industry. There are two types of evidence. The *first*, and perhaps the strongest, is the small number of EEMs that were apparently conducted. Farhar (cited in Faesy 2000) estimated that out of the 13 million total residential mortgages in 1999, less than 1/10 of 1% were EEMs.[95] The *second* set of evidence is that when EEMs were in fact used, it was through non-routine use and individual routines, not well-developed organizational routines.

Individual routines and non-routine use of EEMs by loan officers: During interviews, staff at HERS organizations and SEOs would frequently complain that EEMs were not available within their service areas at most mortgage brokerage offices despite claims by their head offices or secondary lenders. When HERS providers occasionally referred homebuyers to mortgage brokers that were supposed to offer EEMs, homebuyers would often tell them that the brokerage knew nothing about EEMs or even "tried to talk them out of one."[96] It is likely that at one time there was a loan officer that used EEMs at many of these brokerages, but had since left the firm. The very high turnover rate of loan officers, the tendency to work as independent businessmen and women, and the practice of only being paid on commission made it *difficult to establish organizational routines* for obscure practices such as EEMs.

Non-routine use of EEMs by loan officers: For lenders that use EEMs for existing homes, it appears that the process never became routine. In the 2000 survey of Colorado E-Star lenders, the 77% of the loan officers that had completed EEMs only used them five or fewer times over the previous five years,

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[95] Farhar (2000) acknowledges that the data on the total number of EEMs nation-wide is of low quality. Therefore, this percentage should be taken as a rough estimate.

[96] More than a dozen additional interviews with a convenience sample of homebuyers, lenders, realtors, and utilities

which does not suggest routine use. Only 9% used them routinely at a rate of 50 or more times per year. Also, a majority of the loan officers interviewed in Colorado and Vermont who used EEMs made comments suggesting non-routine use of EEMs. Many of them offered the comment that they had not completed an EEM since shortly after their EEM training and had since forgotten about EEMs as an option. Vermont lenders made similar comments. Specifically, when Vermont loan officers were asked if forgetting "about energy mortgages as an option" was a reason that you did not use them more, 53% said it was a very or somewhat important reason. This is not surprising given the one-time trainings and few or no follow-ups by most HERS organizations. Also, when Colorado E-Star lenders were interviewed, about one half had difficulty remembering basic steps in the EEM process, such as if they had the used "HERS ratings to certify [homes for] energy efficiency." The Colorado Housing and Finance Authority had similar experiences with lenders (Colorado Housing and Finance Authority 1998).

Non-routine use of EEMs as evidenced by mistakes, errors, and omissions: Problems that would often occur in the EEM process provided evidence that non-routine use of EEMs was common, and that individuals using EEMs were often poorly trained and/or inexperienced. Moreover, reports of frequent delays in closing dates, failures to meet the contractual obligations, and the substandard retrofit work suggests that many of the activities in Table 10-1 were often not completed on time, not completed well, or not completed at all. During interviews, housing professionals (i.e. loan officers and HERS raters) spoke of themselves and others who did not have the skills or experience necessary to adequately complete EEMs (also see Colorado Housing and Finance Authority 1998; V-HERO cited in Farhar 1997; and Lee et al. 2000). HERS professionals often complained about the variability in the skills of HERS raters to accurately rate homes and to make the EEM process work. According to them, many raters did not help homeowners choose retrofits, find financing, and locate contractors.[97] It is uncertain how frequently these problems occurred, but it seems that the occurrence of at least some of them were common with EEMs. Nevertheless, we should not assume that these were the norm. Many competent

around the United States further suggested that this was not uncommon.

[97] These experiences with HERS raters were conveyed by ERH-VT, ERH-CO, and California EEM facilitators.

professionals were observed in the field, and there are also instances of HERS ratings and EEMs smoothly proceeding to completion.

Often homeowners were also a source of problems in the EEM process. By the very involvement of homeowners who infrequently purchase homes and apply for mortgage financing, many of the activities in Table 10-1 involve non-routine behavior. Homeowners typically find the EEM process complicated, and they lack the skills, knowledge, and information to quickly, smoothly, and correctly do their part to complete EEMs. Also, they usually do not have prior network relations with competent, readily available HERS raters and contractors, nor the skills to assess which contractors are in fact competent. They are unfamiliar with energy efficiency and mortgage finance terms and the paperwork that incorporates HERS rating into the mortgage process. Even with a HERS rating to guide them, many homeowners lack the skills to choose a set of retrofits that are energy efficient (V-Hero cited in Farhar 1997; Faesy 2000; Federal Energy TEEM 2002**;** Lee et al. 2000).

[In the case of the buyer who] takes charge of getting the work done by the brother-in-law for “a great deal” and you come out to inspect the work at the end to find it will not result in the savings [or quality] you initially promised the lender (Faesy 2000, 2-3).

> [One homebuyer] wanted new windows and an HVAC system. Yet, his house bad no attic, wall, or floor insulation and leaked so badly that a blower-door test could not be performed. Once he received his rating and mortgage, the customer spent $13,400 to incorrectly installed windows, even though only $1,000 had been allocated . . . He had the insulation installed incorrectly as well. Post "improvement," the house was leaker [*sic*] than it had been before the rating. The windows contractor was threatening to sue the consumer because the escrow hadn’t been released, that, in turn, occurred because windows installation failed to pass the post-installation inspection. The consumer began to complain that Iris wife and children were freezing (V-HERO cited in Farhar 1997, 45).

Even for the realtors who did sell homes financed with EEMs, it appears that the use of EEMs *never became a comfortable routine*. During interviews with stakeholders and participant-advocates of EEMs, realtors were commonly identified as the strongest on-the-ground opposition to EEMs who would often go out of their way to discourage homeowners from using these mortgages. Energy Rated Homes of Arkansas (cited Walsh 1997a, 321) comment that real estate professionals “perceive that the EEM process will delay” their sales and thus their commission (also see Faesy 2000). Likewise, a proposed HERS rating system was highly opposed by 80% of real estate agents in a survey in Georgia (Burruss 1992).

Given the role of realtors and the way that they are compensated, this is understandable. Realtors are primarily responsible for coordinating the completion of real estate transactions, as discussed in Chapter 7. As the agents of buyers and sellers it is their job to coordinate the activities of the clients and other housing professionals and to keep the process on schedule and smoothly moving forward. Likewise, it is their job to handle any problems that come up, and that is how they seem to view EEMs—as a problem to the timely completion of real estate transactions. The use of EEMs introduces a new set of variables about which they have little experience at trying to control.

Perceptions of non-routine use of EEMs: For the Colorado E-Star lenders that were surveyed, the reason of “too much paper work and hassle” was the most common reason given for not using EEMs, as shown in Table 10-5. The reasons of “complexities,” and “delays” were the “third” and “fourth” most common reasons. The perception or reality of extra paperwork, hassles, delays, and complexities appears to be an artifact of the lack of well-developed organizational routines through which to complete EEMs.

Quantum Consulting reached the similar conclusion that a lack of “organizational practices” to handle EEMs is an important reason for not using EEMs after they surveyed lenders in the Sacramento area of California. Quantum Consulting Inc. noted that . . .

> Lenders, sales agents/realtors, and builders all deal with relatively complicated sales with numerous parties involved. Organizational practices have developed to simplify these processes and reduce risks. Adding new elements to these sales (e.g., energy efficiency and EEMs) runs into organization practice barriers for each of these market actors (1999, 107).

Lee et al. also suggests that . . .

Table 10-5. Reasons for Colorado E-Star lenders not using EEMs.

There have not been enough financial incentives for you and your bank or your clients.	
1. Very important reason	12%
2. Somewhat important	12%
3. Somewhat unimportant	20%
4. Not important at all	52%
5. Don't know	4%
There has been too much hassle and extra paperwork.	
1. Very important reason	20%
2. Somewhat important	36%
3. Somewhat unimportant	16%
4. Not important at all	20%
5. Don't know	8%
There has been too long of an extra delay in processing time for loans.	
1. Very important reason	8%
2. Somewhat Important	24%
3. Somewhat Unimportant	20%
4. Not Important At All	20%
Borrowers did not seem interested when offered an energy mortgage.	
1. Very important reason	20%
2. Somewhat important	24%
3. Somewhat unimportant	20%
4. Not important at all	24%
5. Don't know	12%
The process was too complicated.	
1. Very important reason	8%
2. Somewhat important	32%
3. Somewhat unimportant	20%
4. Not important at all	28%
HERS raters were not available to certify energy efficiency.	
1. Very important reason	12%
2. Somewhat important	4%
3. Somewhat unimportant	8%
4. Not important at all	40%
5. Don't know	36%
Borrowers thought the costs of HERS ratings were too high.	
1. Very important reason	4%
2. Somewhat important	24%
3. Somewhat unimportant	12%
4. Not important at all	28%
5. Don't know	32%

(Source: 2000 survey of Colorado E-Star lenders, see Appendix A).

> . . . lenders were concerned that an EEM will complicate the loan process and increase the lender's costs. Similarly, lenders prefer to stick with established practices, and there is organizational resistance to change" (Lee et al. 2000, 179).

Also see Farhar, Collins, Walsh (1996; 1997) and Farhar and Eckert (1993).

Insufficient and Ineffective Capacities for Establishing New Routines for EEMs

HERS organizations did not have the organizational capacities to significantly reshape the process of financing and selling existing homes. Their main source of influence—the use of education and incentives-- were not very effective. Why did EEMs not have more appeal with housing professionals? Also, to the extent that lenders and realtors did want EEMs to succeed, why were they unable to establish the routines needed for EEMs to succeed? There appear to be two main reasons why the capacities of the approach of subsidies, advertising, and trainings were insufficient to restructure the day-to-day routines of the industry. *First*, the incentives and benefits of EEMs were a poor fit with the existing values and routines of the housing industry. *Second*, and perhaps most importantly, stakeholder organizations did not themselves have the capacities to restructure their own industry to include routines for EEMs.

Lack of fit: To the disappointment of HERS organizations, lenders and realtors were not very motivated by the benefits and incentives of using EEMs. By benefits, I mean those intrinsic advantages that are associated with EEMs, such as being able to lend larger sums, improve substandard homes, and qualify borrowers that might not qualify. By incentives, I am referring to the additional financial rewards that have been occasionally offered by government offices such as offering prizes to loan officers who originated the largest number of EEMs or reduced interest rates.

Most loan officers that participated in the 2000 survey of Colorado E-Star lenders and the 2000 survey of Vermont EEM lenders (see Appendix A and B) seemed to view the benefits and incentives of EEMs as substantial. When specifically asked if the lack of benefits (and incentives, which was implied as well) was a reason for not using EEMs, most of them responded that it was not a significant reason (see Table 10-5).

However, a few of the lenders pointed out that, although significant, these benefits were not unique. Lenders and realtors could easily reap similar or greater benefits from traditional sets of routines without the additional hassles, complexities, and risks associated with EEMs. A loan officer from Denver, Colorado explained that the process of mortgage lending usually proceeds smoothly. However, problems can arise because of the homebuyer's finances or the physical condition of a home. In these cases, EEMs are only one option among many to solve these problems and lend money to homebuyers.

The physical condition of the home: If a home is substandard because of a bad roof, a broken furnace, no attic insulation, or being extremely drafty, mortgage brokers will often not want to finance it.[98] If the borrower defaults, the secondary mortgage lender would be stuck with a home that would be difficult to resell. Furthermore, substandard homes often appraise lower than the prices negotiated between the buyer and seller. Because lenders will seldom loan more for a home than the appraised value of it, deals on substandard homes can fall apart, according to the Denver loan officer.

In cases of substandard homes, lenders and realtors will often intervene into technological choices that normally belong to the buyer, and encourage or insist that homes are brought up to the standards of the community. One option is, of course, EEMs to finance any energy improvements. However, other solutions are more routine and easier. According to the Denver loan officer, lenders and realtors can . . .

- encourage the seller to pay for the needed improvement.
- convince the seller to reduce the purchase price by an amount that equals the cost of the needed improvement.
- have the buyer purchase the property at a reduced price and take out a personal or home improvement loan to finance the repairs and improvements.

The borrower's finances: When a homebuyer cannot qualify for enough financing to purchase the home of their choice, lenders will try to find a solution. In addition to EEMs, they have many options. According to a Denver loan officer these include . . .

[98] Loan officers usually hear about homes' technical problems from their bank's appraiser who reports on the general condition and market value of homes or they perhaps hear from the homebuyer of defects discovered by the

- helping homebuyers improve their credit rating by locating mistakes in their credit report or finding mitigating factors to explain the incidences that harmed their credit.
- using their discretion to increase a borrower's debt-to-income ratio by the allowed 2% because of certain situations such as if borrowers have a secure job.
- having the borrower increase their down payment and thus decrease the amount they need to borrow.
- persuading sellers to decrease the purchase price.
- using other conventional mortgage products (offered by secondary lenders such as the FHA and State Housing and Finance Agencies) to help low-income homebuyers finance a home.

A California loan officer noted that there are many other strategies that they can employ to make money at lending. In the mid to late 1990s the strategy was refinancing higher-interest loans with new, more attractive interest rates. Since the year 2000, it has been the use of piggyback loans that eliminate the need for cash to make down payments, which are incompatible with EEMs.

The existing home side of the housing industry is really about financing and selling houses as quickly as possible. The Denver loan officer stated that, even though EEMs are great products and he is concerned about energy efficiency, he never uses EEMs to improve homes beyond the energy efficiency standards of the housing market. He only uses EEMs to improve homes up to the standards of the market. "I could use them more, but you have to remember my job is to finance houses as quickly as possible and make money at it. If I can also make a few of the homes more energy efficient . . . I will, but it is not my job." This was similar to comments made by other loan officers, brokers, and realtors that building a home to energy codes "was efficient enough," or that all the homes in "my market are already energy efficient." The Denver loan officer himself had originated about five EEMs for existing homes per year over a period of a few years.

A retired banker and realtor from the state of Washington had a similar, much more cynical

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homebuyer, according to the Denver realtor.

viewpoint. “Bankers portray themselves as the friendly-neighbor-type, but they are not your friend. They just want to make money . . . the deals they offer are the best for them, not for you.”

So then why do any lenders and realtors use EEMs if they already have these tried and proven routines to solve problems and get people into homes? On rare occasions, these conventional problem-solving routines do not work and EEMs remain an option, suggested the Denver loan officer. However, another reason seems to be the attitudes and values of the individual loan officers and brokers. The Denver loan officer and some of the others participating in the 2000 survey of Colorado E-Star lenders and 2000 survey of Vermont EEM lenders (see Appendix A and B) described themselves and other EEM lenders as holding certain values and perspectives about the mortgage lending industry. They suggest that lenders who recommend EEMs to their clients are exceptionally customer orientated and/or care about energy efficiency and economic equality. The survey of Colorado and Vermont EEM lenders also suggested that these lenders were motivated by values for the environment and economic equality (Table 10-5), which is perhaps common among first adopters. Also, Faesy (2000) commented that there are some customer-focused loan officers and brokers who are looking for a market niche.

Capacities of Stakeholders

We have discussed reasons why EEMs were not a good fit with the values and routines of the existing home side of the housing industry. However, there has been some minimal support among mortgage lenders and other stakeholders for EEMs to succeed. For example, organizations such as Fannie Mae, the FHA, and the National Association of Realtors actively participated in the National Collaborative, HERS Council, and RESNET. To the extent that stakeholders have wanted EEMs to succeed, what are the reasons they have not been able to restructure their industry to use EEMs?

Mortgage lenders and realtors, themselves, have limited organizational capacities to control the day-to-day routines of many aspects of mortgage lending. The existing home side of the residential housing industry is extremely fragmented and decentralized. There is very little centralized control and coordination over the process of financing and selling homes. Clearly, this hinders the ability of stakeholder groups to proactively build routines to support EEMs.

Mortgage lending: As mentioned, most of the mortgage lending industry is fragmented into mortgage brokerage offices, loan officers, loan processors, and secondary mortgage lenders, which are commonly separate businesses that have little control over the business practices of the others. Most secondary mortgage lenders such as Fannie Mae, Freddie Mac, and the FHA do not employ their own brokers or loan officers. Thus, they have no direct control over what mortgage products most brokers offer to homebuyers. All they can do is offer to buy mortgages from the mortgage brokers who originate these financial products.

As described in Chapter 6, mortgage brokerage firms, in turn, have relatively little control over loan officers who are also often self-employed businessmen. Mortgage brokers oversee the activities of loan officers within the mortgage brokerage office, and loan officers find borrowers, help borrowers fill out loan applications, and handle bank closings for the mortgage brokers. The brokers then bundle up the mortgages and sell them to the secondary market. Because loan officers are typically independent businessmen and women, brokers cannot realistically order loan officers to be trained in the use of EEMs, nor demand that loan officers incorporate the use of them into their daily routines. Trying to establish day-to-day routines in the industry is probably made more difficult because loan officers have such a high turnover rate. Once loan officers become well trained, they often leave a brokerage firm or the mortgage industry within a short period of time (often a year or two). This high turnover rate appears to be because of the cyclic nature of the housing market and also the commission-based, independent contractor model of doing business that makes it difficult for many loan officers to survive in the profession.

Realtors: The situation is similar. Most real-estate brokers are small businesses that serve local markets, also as discussed in Chapter 6. Brokers typically contract with real-estate agents who are also independent businessmen and women that are paid on commission.

The point is that there is simply no single entity that can restructure any significant portion of the mortgage lending or real estate industries to give new innovations a foot hold. This is in contrast to many other industries, such modern automobile and major home appliance manufacturers that have been more highly concentrated. This is also a close comparison to the approach of using independent agents to distribute and sell Singer sewing machines and Ford automobiles that tormented Isaac Singer and Henry Ford, respectively, as described in Chapter 3. The use of independent agents did not provide the degree of control and coordination that is often needed to structure new systems arrangements.

Homebuyers and owners: Of all the stakeholder groups, this is the one that typically lacks any organizational capacities whatsoever to use EEMs, for technological change, and for system building. Unfortunately for the success of EEMs, much of the responsibility to make EEMs work rests with them as Table 10-1 indicates. By referring to the lack of organizational capacities of homeowners, I am not suggesting that they are system builders. Clearly, they are not. Nevertheless, the households of homebuyers are key organizational participants in EEM process.

The internal structure of homebuyers/owners is organized around domestic routines, not technological change, as discussed in Chapter 7. Although the members of most households are probably intelligent enough to learn how to complete an EEM, most do not have the existing organizational or even individual routines to do so including the specialized knowledge, skills, and network contacts needed to easily complete the activities listed in Table 10-1. Instead, they are preoccupied with routines for domestic activities including marriage, child rearing, housework, leisure, and also of course work outside the home for income. In addition, some domestic and work routines conflict with completing EEMs. For example, to bring an EEM to completion can require being available during the day to meet with HERS raters and contractors (Federal Energy TEEM 2002). Furthermore, we should not be at all surprised that households never develop lasting organizational routines for technological change, because households do not frequently make major consumer purchases affecting residential technology.

Because of the lack of pre-existing routines, homeowners often have numerous problems with the EEM process. These range from struggling with strange forms and terminology (Federal Energy TEEM 2000), to not providing sufficient oversight and coordination of the various parties involved in an EEM, to not being able to find qualified contractors. Subsequently, most homebuyers find the process of completing an EEM quite complicated and end up “in over their heads” (Lee et al. 2000, 176).

To elaborate on a particularly point, homeowners can have a great difficulty locating qualified contractors to place bids and complete retrofit work on short notice because they are not well-networked in the housing industry. Some retrofit work requires special equipment and training that many contractors do not have, such as blower equipment to place dense-packed cellulose into wall cavities. Neither are all contractors of the same skill level and professionalism (Faesy 2000, 3; Federal Energy TEEM 2002; personal communication with Alaska and California; from interviews with housing and HERS professionals in Alaska, California, Vermont, and Nebraska, and also see Lee et al. 2000). Even well-established general contractors that do remodels and retrofits for a living can sometimes have a difficult time finding qualified subcontractors.

Likewise, homeowners often fail to coordinate the activities of HERS raters, contractors, realtors, and lenders, which is absolutely essential to keeping an EEM on schedule so as to not delay the closing on a home and release all the escrow funds on time. The process takes a commitment of time that most home owners are not prepared to actually make, and seems to conflict with domestic routines during the particularly busy period during a move to a new home and settling into it (Federal Energy TEEM 2002).

The Approach of Facilitating EEMs

We just discussed attempts at system building by primarily relying on education and incentives to promote the use of EEMs. However, instead of merely advocating the use of EEMs, some organizations have adopted a more hands-on, participant-advocate approach to system building. As mentioned above, these are called EEM facilitators. These organizations have internalized most of the EEM process by establishing their internal routines to conduct most of the activities in Table 10-1 to complete EEMs for existing homes. *By setting up these organizational routines, facilitators have had much more control over these activities than if they would have left them to lenders and homeowners.* Instead of advocating from the periphery of the industry as had many other EEM advocates, these EEM facilitators became active participants in the day-to-day activities of the residential housing industry at the local level.

EEM facilitation has been successfully conducted by only eight or so for-profit firms in California and a non-profit in Vermont. With little or no subsidies these organizations have succeeded at retrofitting thousands of homes in their communities through the EEM process, which would not otherwise likely have been made more energy efficient (Faesy 2000). The first California firm to facilitate EEMs was the Energy Efficient Mortgage Service Company (which later became EEMs, Inc.), which then led to the seven other California firms listed below.

- Federal Energy Services (which became the Federal Energy TEEM).
- Affordable Home Energy
- H&L Energy Services
- Mortgage Training Services
- Consumer Energy Management Consulting (CEMCO)
- Bobbi Glassel & Associates
- Performance Energy

Because of the success at facilitating EEMs in California, participant-advocates of EEMs in Idaho, Maine, Wisconsin, New Hampshire, and New York attempted to develop EEM facilitation services. Of these non-California organizations, it appears that only Energy Rated Homes of Vermont (ERH-VT) was able to facilitate a significant number of homes.

As will be discussed below, facilitators were quite successful in their communities from 1993 to about 2003. They facilitated the completion of thousands of EEMs for existing homes that resulted in retrofits that greatly increased the energy efficiency of these dwellings. This localized success and also the failure of it to spread nation-wide can be, in part, explained by their organizational capacities and lack of capacities for facilitating EEMs and for system building.

Organizational Capacities for Facilitating EEMs

The system building strategy that was taken by the leadership among EEM facilitators was twofold. *First*, they internalized into their internal management hierarchy a set of routines for some or most of the activities needed to complete EEMs in their local communities. Once established, these were effective routines to gain information about, to control, and to coordinate existing system activities.

However, since their service area was their local housing market, this alone did not allow for system building of any significant scale. Therefore, and *second*, a few of the facilitators expended significant efforts to help other individuals sent up their own EEM facilitation services in other communities into a small network of EEM facilitators, and thus ratchet up their organizational capacities for facilitating EEMs. They had some local success, but found it very difficult to spread the approach of facilitating EEMs beyond the region of Northern California. Vermont was an exception.

The facilitation of EEMs is an instance were the capacities for information, control, and coordination cannot be easily subdivided into discrete sets of routines for information, control, and coordination, respectively. It is conceptually easier to discuss three functional sets of routines that each contained routines for information, coordination, and/or control. These functional sets are routine(s) to 1) obtain referrals to homebuyers that were likely candidates for EEMs, 2) sell EEM facilitation services to homebuyers, and then 3) actually facilitate the EEM process.

Routines to gain access to homebuyers: Facilitators aggressively networked with loan officers, mortgage brokers, and processors and occasionally other professionals. These were simultaneously *routines for control and for information*. These routines were to gain influence in the lending community and with individual lenders with the ultimate goals of obtaining referrals to homeowners and cooperation with the facilitation process. Specifically, facilitators used the following routines.

- Group training sessions with lenders and other housing professionals
- One-on-one trainings with lenders and other housing professionals
- Making social visits and attending events with lenders and other housing professionals

All three routines were primarily about establishing relationships with the lending community. However, the trainings about how to use an EEM and energy efficiency were largely ceremonial, because the facilitators would handle essentially all the details of actually completing an EEM. The goal of the facilitators was to gain access to new groups of brokers and loan officers and also to increase their familiarity and comfort level with the idea of having EEMs facilitated.

The most important of these three routines was likely the last—the social visits. As discussed above, the benefits of using EEMs were not terribly unique, and one-time trainings are not very effective. Therefore, the facilitators went further and invested ongoing social and business relationships with the mortgage lending community and individuals. "You have to become part of the lending community" to become appreciated, said a California facilitator. Another facilitator stated that you need to be a good "Schmoozer." This meant taking brokers out to lunch, buying holes at their benefit golf tournaments, bringing donuts when you stopped by their office, and attending their Christmas parties. However, some facilitators did less "schmoozing" than others. ERH-VT mostly relied on the interest rate reductions of the Vermont YESS EEM to generate calls to them from both lenders and homebuyers (Faesy 2000). As social exchange theorists would say, the facilitators were establishing "social associations because they expect[ed] them to be rewarding" (Blau, 1994: 152-156) in terms of the referrals they received.

Sales: Once facilitators had a referral to a homebuyer, they would call that homebuyer to sell their EEM facilitation services. This was, of course, a *routine for control*. Facilitators specifically told lenders not to attempt selling EEMs to borrowers. Most facilitators strongly believed that they could explain an EEM to a homebuyer much better than a loan officer, and claimed a success rate around 90%.

Facilitating the completion of an EEM: The actual facilitation of EEMs involved the coordination of the activities of HERS raters, contractors, lenders, realtors, and homeowners. Facilitators either coordinated the following activities or conducted these themselves.

- Arranged for a HERS rating.
- Helped homebuyers choose cost effective energy improvements.

- Wrote and sent bid sheets to contractors (some facilitators did their own construction work).
- Filled out paper work for the lender.
- After the sale of the home closes, arranged for all the contractors to have access to the property at the same time.
- Arranged for the HERS rater to inspect the construction work and conduct a post rating.
- Completed additional paperwork for the lender.
- Arranged for funds to be paid from escrow to the contractors and the facilitators themselves.

Facilitators claimed that they could do a much better job at most of these actives than homeowners or loan officers because they engaged in these routines in high volume and also could eliminate some of the activities in Table 10-1. For example, since facilitators were already networked with contractors and HERS raters that were "competent, courteous, clean, and prompt" (Faesy 2000, 3), facilitators did not have to search for qualified professionals with each new job. Likewise, because the contractors had established business relationships with the facilitators, the contractors would rely on bid sheets (technical specifications) instead of insisting on site visits, which saved time and avoided hassles for all parties. Also, facilitators would arrange for all contractors to make retrofits at the same time so none of them would have to wait for the money to pay them being released from escrow. For these reasons, facilitators were able to pay top dollar in a timely manner to contractors, which helped ensure their availability for future EEMs (also see Federal Energy TEEM 2002).

Organizational structure: On a per organization basis, the organizational size and sophistication of EEM facilitators was comparable to the HERS organizations using the approach of subsidies, advertisings, and trainings. Facilitators were also small organizations, and seldom had more than two or three staff in their organization, and usually no more than one or two full-time equivalents were devoted to EEM facilitation. EEMs, Inc. was an exception and at its peak had 5 or 6 employees devoted to EEM facilitation**.** Once again, this small organizational size placed real limits on the capacities available for system building. Also, some of them operated as general contractors, and thus heavily relied on network relationships with other organizations to mobilize the additional routines that they needed to complete EEMs including contractors, HERS raters, lenders and realtors. This left facilitators with little direct control over much of the housing in their community, and they were largely at the mercy of larger changes in industry.

Financial resources that could be flexibly used: These resources were actually available to many facilitators in often fairly significant dollar volumes. The original entrepreneur of EEM facilitation from California is perhaps the best example. He had enough financial resources from a previous successful business to invest in developing his organizational model to facilitate EEMs in the early 1990s. Over the years, EEM facilitation proved to be quite profitable for him, and some of that profit was available to use for additional system building. During peak years of operation, the original entrepreneur and the firms of a few other facilitators were each responsible for one to three million dollars in retrofits from which they earned a 10% commission if not significantly more.[99] All of the facilitators that were interviewed stated that EEM facilitation was very lucrative for them or could be.

This organizational model used by the firm of the original entrepreneur *was orientated toward growth and system building*. As their volume of sales increased, he would hire additional staff to fill any of the established routines and/or subdivide a set of routines into additional sets with new job descriptions. Most facilitators, including the original entrepreneur, set up an organization that was very much aimed at profit and growth in contrast to the non-profit participant-advocates that used the approach of subsidies, advertisements, and trainings.

His firm developed an internal division of labor and set of management routines that allowed him to coordinate the various routines for the day-to-day activities of facilitation. The inventor of EEMs managed much of the day-to-day operations, and specialized in networking with the loan officers and

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[99] To understand exactly how lucrative facilitation was, I need to elaborate. Often the facilitators had a different formula for calculating their fees. However, the facilitators that operated as general contractors earned 10% off of a retrofit contract. Their charge was for coordinating the construction and paper work associated with bringing the EEM to completion. This 10% did not typically include charges for subcontractors and for the hardware they installed. If they facilitated $3 million of contracts per year, that would be $300,000 dollars in personal income per year for a facilitator.

brokers to maintain a flow of referrals into his firm. His assistant supervised the field staff that installed the retrofits and oversaw any subcontractors that were used. The firm often employed two or more of these field staff. It also sometimes employed staff that specialized in making sales to homeowners and customer relations.

Once established, the above routines became part of the organization's capacities for information, control, and coordination to maintain the new systems arrangements among raters, lenders, contractors, and homeowners that they had established. Also, quite importantly, this organizational model allowed him the time and freedom to develop additional organizational capacities for further system building because the day-to-day details of facilitating EEMs could proceed without constant attention from him. He personally staffed most of these capacities for system building at his firm.

C*apacities for control, coordination, and strategic planning: First*, he allocated a fair amount of his own personal staff time to lobbying the federal government for laws and policies to support EEMs. *Second*, he spent time on the internal growth of his firm as mentioned above. *Third*, he advocated and helped other individuals start their own facilitation business. A substantial portion of the California facilitators had worked for his firm or had been trained by it before starting into their own facilitation business. He also attended conferences around the country to promote facilitation as a lucrative business idea and to encourage energy efficiency in the existing housing stock. Some of the other facilitators participated in these activities to a lesser degree.

All the facilitators interviewed stated that they found plenty of time for *strategic planning*, although these activities do not appear to have taken the shape of fully developed routines. One of the California facilitators commented that thinking about how to make EEMs work "occupied most of his day." He meant that he was constantly strategizing while driving to the job site or while engaging other parts of the facilitation process that allowed him time to think about how to "make EEMs work."

However, an obstacle to strategic planning and evaluation for some of the facilitators appears to have been little or no *separation between operational and strategic management*. Many of the facilitators were entrepreneurs that created and used their own unique model of facilitation and were reliant on a particular mortgage product. Some of them appeared very resistant to reconsidering their approach to facilitation. Staff at one office reported significant conflict between the original facilitator-entrepreneur and those who wanted to make changes.

These system-building activities of EEMs, Inc. and others did have some effect. EEMs, Inc. did help draft Mortgagee Letter 93-26, which was the first truly workable EEM for existing homes. By pointing to its success, EEMs, Inc. was directly or indirectly responsible for the formation of eight or more other organizations that successfully facilitate mortgages. ERH-VT was also active in encouraging EEM and HERS advocates in New York and New Hampshire to consider and/or try the facilitation of EEMs.

However, the organizational capacities of these facilitators and their successes need to be kept in context. The organizational capacities for system building of these facilitators were really quite minimal in absolute terms, and for the most part only had a local impact and very sporadic influence nation-wide. It was overall very difficult for them to influence government to make relatively minor changes in policies that still could have had substantial benefits for EEMs.

Also, it proved difficult for them to convince others to use the facilitation model, even though all California facilitators describe the work as very profitable. Although the organizational routines used to gain access to homebuyers seemed to usually be effective at gaining influence over lenders and obtaining information about homebuyers, it was difficult find people to staff these routines. When EEM facilitators were asked, most stated that facilitators needed to have a unique set of skills and work experience. *First*, to obtain referrals from homeowners, it was essential to have individuals be willing to very aggressively network with bankers. As noted above, you had to be willing to "schmooze." One facilitator commented that it was not particularly fun to go back to the same mortgage banker office every few days and recite the same reasons why lenders should use EEMs. It should be noted, the facilitators were not exactly selling anything to the loan officers, just asking for favors. He also described it as humbling to hang around brokerage offices until they gave you a referral often just because you brought them donuts and not because they really wanted or needed your facilitation services. In the absence of additional financial incentives for lenders, this was essential to facilitation because referrals to homebuyers were essential.

Second, other skills and experience were also extremely important for businesses that facilitated EEMs. All facilitators stressed that it was imperative to have staff with a working knowledge of residential construction, energy efficiency, and mortgage banking. There are very few people that have all these skills and are willing to use them, which made it very difficult for a loan individual to start up a facilitator business as a one-person office.

Also, as mentioned, they had no ability to control the direction and pace of change in the residential housing industry, and it was changes in mortgage banking that contributed to the near collapse of the market for EEMs in California and Vermont. First of all, in California, the costs of real estate climbed faster in the Bay and Sacramento area than borrowing limits for the FHA and Fannie Mae were increased by Congress, which meant fewer and fewer existing homes were eligible for FHA and Fannie Mae EEMs. *Second*, Fannie Mae came out with a “piggy back” mortgage product that captured much of the market for the financing of homes for lower-income and first-time homebuyers that were the largest users of EEMs for existing homes. This “piggy back” mortgage was not compatible with EEMs. *Third*, in Vermont, interest rates for conventional mortgages dropped lower than the rates for the state sponsored YESS EEM, and lenders lost much of their interest in the energy efficient mortgage product used by the facilitator in that state (Faesy 2002).

These point to one of the largest problem faced by facilitators. They have had no way to control and coordinate the rate and direction of change in mortgage products. A century ago, captains of industry found a solution to an analogous set of problems, as discussed in Chapter 4. They vertically integrated their factories both down and up to control parts of their industry that were crucial to their survival, and, quite importantly, they also set up their own R&D programs to continually research and develop their existing products and to research and develop entirely new products and/or services. This was invaluable for them, particularly during the Great Depression. They were able to control the pace and direction of change in their own industries. Many of those manufacturers that failed to do so during the Great Depression went bankrupt, while many of those that had the ability to control direction and pace of technological change in their own industry actually came out of the Great Depression with a larger and more profitable firm.

Of course, this solution was far beyond the immediate means of these EEM facilitators. However, this historical comparison makes an important point. Systems are always in a state of change, and to survive over the long-term it is important for an organization to have a full set of sophisticated capacities for system building. This includes sets of organizational routines to engage in the continual development of their core technologies and products. Having a novel invention such as the EEM is not enough.

Moreover, just because EEMs are an institutional innovation instead of a technical innovation does not mean that an R&D program or analogous set of organizational routines would not be useful for system building. A fundamental process of system building is designing new sociotechnical arrangements in the abstract (i.e. either social or technical inventions) and then evaluating their fit with the existing system, adjusting that fit, and further iterations of reconceptualizing, evaluating, and adjusting. This can either be an ad hoc process using what every organizational capacities can be co-opted for the system building endeavor, or it can be driven by a well-developed set of organizational capacities that are matched to conceptualizing the invention, evaluating its fit, and adjusting that fit. The great utility of R&D capabilities has demonstrated the utility of dedicating formal structures within an organization for these tasks.

Evaluation: Facilitating Versus Subsidies, Advertising, and Training

The goals of HERS and EEM advocates have been to integrate EEMs into the day-to-day activities of the housing industry and, thus, transform decision-making about technology in favor of energy efficiency. The extent to which each approach has achieved this goal will be evaluated by comparing the two approaches according to (1) the number of EEMs that they had facilitated or otherwise caused, (2) actual improvements in energy efficiency, and (3) the creation of a viable, long-term set of routines to complete EEMs without subsidies. By all three of these criteria, EEM facilitators seem to have been more effective, although their successes were on a more limited local scale.

Number of EEMs: It appears that facilitators generated more EEMs per capita in their service areas than HERS providers that used subsidies, advertising, and training. This has been the conclusion of others as well.[100] However, the data are incomplete, especially for HERS providers.[101] Table 10-6 contains the number of EEMs or estimates of the number of EEMs generated by HERS providers that use the approach of soliciting subsidies, advertising, and training. The table includes available data from V-HERO of Virginia, ERH-AR of Arkansas, CHEERS of California, and ERH-CO of Colorado. (No reliable quantitative data is available from ERH-VT and ERH-MS on their approach of subsidizing, training, and advertising or from HERS providers in other states within this case study.)

Table 10-6. Known and estimated completions of EEMs: The data is for both existing and new homes that were completed due to the activity of four HERS organizations participating in the pilot programs and study.

HERS provider	**1993**	**1994**	**1995**	**1993-1995**	**1999**	**Service area##**
V-HERO, Virginia*	0	200	729#	929	-	6.6 million
ERH-AR, Arkansas**	-	-	-	47	-	2.5 million
CHEERS, California***	~35	~30	~310	~775	-	31.6 million
ERH-CO, Colorado****	0	0	-	-	~470	3.7 million

\# V-HERO estimates that 500 of the EEMs in 1995 were for 2% stretches for new homes.
\## Population estimates are for 1995 and provided by the U.S. Bureau of the Census.
* Numbers provided by V-HERO and cited by Farhar (1997).
** Numbers provided by ERH-AR and cited by Walsh (1997a).
*** Numbers provided by CHEERS and cited by Collins (1997b). Because of its inconsistency with other numbers reported by Collins, the number of EEMs for 1995 is suspected of being too large.
**** Numbers were estimated from a survey conducted by the author in July 2000 of a list of lenders participating in the E-Star lenders program. This estimate is likely low because non E-Star lenders likely originated at least some EEMs.

On the other hand, EEM facilitators have been able to accurately determine the number of EEMs that resulted from their efforts. This is largely because they handled the paperwork that was essential to

[100] Farhar and Eckert (1996), Farhar et al. (1997), and Farhar (2000) stated that very few EEMs have resulted from the approach of subsidies, marketing, and training.
[101] As mentioned above, there is no reliable national database on EEMs. Fannie Mae and Freddie Mac do not denote EEMs in their database. The FHA does record EEMs in their CHUMS database, but HERS and EEM advocates have little confidence in its accuracy, and it is not easy to associate EEMs with the activity of specific HERS providers. GMAC and the Veterans home administration do keep track of EEMs, although these appear to be two of the least commonly used EEMs. Also, the CHUMS database does not delineate between EEMs for new and existing homes.

closing each EEM. In their local Northern California market, the California EEM facilitators together completed

- 36 EEMs in 1994,
- 140 EEMs in 1995, and
- about 50 EEMs in the first two-and-one-half months of 1996 (Collins 1997b).

Also, both EEMs, Inc. and the Federal Energy Team reported (during interviews with the author) that from 1999 to 2002 they were facilitating about 350 EEMs per year, and other EEM facilitators were active in Northern California during this time as well. Also, ERH-VT began EEM facilitation services in 1998 and had facilitated a total of 41 EEMs by May 2000 in Vermont.[102] During the summer of 2000, ERH-VT had increased their volume of EEMs to one and a half per week, and was on target for about 50 for the year with a statewide service area of 600 thousand people.

It appears that EEM facilitators were able to generate at least a comparable and probably significantly greater number of EEMs on a per capita basis than most HERS organizations, although the data makes it difficult to drawn definite conclusions. For example, the combined service area for the California facilitators was Sacramento, Fresno, and Santa Ana, which had population 2.4 million people. This was a much smaller service area than that of the HERS organization, CHEERS, which had the entire state of California. Nevertheless, they still facilitated almost ten times more EEMs than CHEERS generated on a per capita basis for year 1995.

Tangible improvements in the energy efficiency of homes: There is significant evidence that the efforts of EEM facilitators led to more tangible improvements in the energy efficiency of homes than that of HERS organizations using the approach of soliciting subsidies, advertising, and training. The largest reason is that many of the EEMs generated by these HERS providers cannot be attributed to significant increases in energy efficiency. A large majority of the EEMs generated by these HERS providers were FHA EEMs for *new homes*, which only had to meet the 1992 model energy code (MEC 92) to qualify for

[102] These were VHFA YESS mortgages that offered an interest rate reduction.

this FHA mortgage product.[103] MEC 92 was already code in the large majority of states and major urban jurisdictions by the mid-90s or earlier. Thus, many of these EEMs for new homes were likely rewarding homebuyers who purchased the same house regardless, and probably did not result in significant energy efficiency improvements.[104] For example, V-HERO indicated that approximately 500 of their 929 EEMs were 2% stretches for new homes (Farhar 1997). Also, the 2000 survey of E-Star lenders in Colorado found that approximately one half of the EEMs originated in the state by ERH-CO between 1995 and summer 2000 were 2% stretches for new homes with probably little increase in energy efficiency (see Table 10-5).

On the other hand, EEM facilitators focus on EEMs for *existing housing* and thus retrofitting typically provides opportunities for substantial improvements in energy efficiency. Existing homes that are financed with EEMs are typically older homes built in the 60s or earlier with little insulation and weather stripping, and an outdated HVAC system. Through the EEM facilitation process these homes are retrofitted with approximately $8,000 in energy improvements. The facilitators in California and Vermont stated that these retrofits typically included . . .

- new, higher energy-efficiency HVAC systems
- new dual pane windows, weatherization
- duct sealing
- more attic and wall insulation
- sun screens
- whole house fans
- new, high energy-efficiency water heaters

[103] One of the most common EEMs for new housing is the FHA 2% stretch. This is currently qualified by MEC 1992 in Mortgagee Letter 93-26 (Retsinas 1993), and was earlier qualified by MEC 89 in Mortgagee Letter 89-25 (Apgar 1989), and thus do not often, if ever, result in an increase in the energy efficiency of the housing stock.

[104] By 1996, a substantial majority of states had already required that new homes meet MEC 1992 or more stringent standards (Bodzin 1997). By 2004, there were 36 states that had adopted MEC 1992 and 31 had adopted a more stringent energy code. Even in the 14 states that did not have a statewide energy code, a large majority of local jurisdictions had adopted MEC 1992 or higher (U.S. Department of Housing and Urban Development n.d.).

After these homes have been retrofitted, an independent HERS rater conducts a post rating to verify correct installation. Table 10-7 is of the energy savings that resulted from EEM facilitation in Vermont. After being retrofitted through the EEM facilitation process, the average existing home became 100% more energy efficient and reduced energy expenses by over $1,000 per year. Interviews with California facilitators indicate that these results can be reasonably generalized to California.

Creation of a viable, long-term set of routines to complete EEMs without subsidies: EEM facilitators were able to meet this criterion for approximately a decade at the local level. They established a self-supporting set of organizational routines for the activities to bring EEMs to completion. Collins (1997b) and Faesy (2000) agree. They both note that EEM facilitation has been successful without any direct subsidies.

Table 10-7. Average results from EEMs for existing homes: These homes were facilitated by Energy Rated Homes of Vermont from November 1997 to May 2000.*

Metric	**Results**
Number of completed EEM jobs	41
Average initial rating score	56.4 points (2 Stars +)
Average post-improvement rating score	73.8 points (3 Stars +)
Average rating score increase	17.4 points
Average annual energy savings	67.4 MBtu
Average annual energy cost savings	$1,075
Average financed investment in energy improvements (and fees)	$7,194
- Mechanical systems financed investment	$4,356
- Weatherization financed investment	$2,596
Average annual mortgage increase	$586
Average cash flow generated	$489 ($41/month)

*Table adapted from Faesy (2000).

In contrast, when the subsidies for advertising and training were discontinued, HERS organizations were forced to soon discontinue much of their use of the approach of subsidizing ratings, advertising to homeowners, and aggressively training lenders about EEMs. V-HERO of Virginia declared bankruptcy in 2000, and ERH-AR (Arkansas) discontinued its operations in about 2002. Both EHR-CO and CHEERS switched to an emphasis almost entirely on rating new construction. Also, the comments of most respondents in the 2000 survey of Colorado E-Star lenders suggested that once the training and advertising was terminated, the mortgage brokerage offices that had been offering EEMs were no longer using them extensively or at all within a few years.

However, as described above, EEM facilitators are now facing some daunting challenges due to changes in the mortgage industry, and their future is very uncertain. Nevertheless, EEM facilitators have arguably created set of organizational routines to generate EEMs that were more enduring than the approach of subsidizing ratings, training, and advertising to promote EEMs.

Integrating HERS Ratings into the Routines of the New Housing Market

In the late 90s and early 00s, most HERS organizations had substantially shifted their focus away from ratings for existing homes and EEMs and toward ratings for new homes. HERS providers were still using the same general approach of soliciting subsidies, advertising, and training of housing professionals as a way of generating demand for HERS ratings for these new homes, and they were struggling to generate demand for their ratings. These difficulties caused serious budget problems for some HERS providers. It was the conclusion of Farhar (2000) and Plympton (2000) that without the continuation of significant levels of subsidization, very few if any of the HERS programs were yet capable of surviving on their own, and would continue to need significant levels of support in the foreseeable future. However, HERS providers could not depend on those subsidies. According to a number of HERS professionals, the DOE had grown pessimistic about HERS ratings ever generating any significant market demand. Indeed, it had already terminated most it’s funding for HERS activities. If other funders such as SHFC, SEOs, or state legislatures decided to do similar, the organizational infrastructure of the home energy rating system would collapse. This was generating some anxiety among HERS professionals.

However, things changed for the better. From the year 2000 onward, there was a significant and steady increase in demand for HERS ratings. One of the reasons was the EPA Energy Star program, which became the labeling system for essentially all HERS providers by 2001. The volume of new homes that had an Energy Star rating doubled every year from 2000 until 2003 (U.S. Environmental Protection Agency 2005a), and in 2004 the number of new homes that had a rating was approximately

130,000. Most of these were for new construction. In 2004, almost 10 percent of new home construction had an Energy Star label and was certified to be at least 30 percent more energy efficient than MEC 92 (which has formed the basis for most energy codes around the country) (Lee 2005).

There are several factors that explain the surge in the volume of HERS ratings. All of the reasons involve large structures that have little to do with the small organizational model of the initial HERS providers. *First*, the organizational capacities of a second generation of HERS providers can, in part, explain this surge in volume of HERS ratings. Specifically, these second-generation HERS providers had a fuller set of organizational capacities that allowed them to better control the market for HERS ratings on the new home side of the residential housing system. I will define the first and second-generation more precisely below. For now it will suffice to say that the first-generation HERS providers started out in the mid 1990s as non-profits and government programs, and that the second-generation HERS providers were usually for-profit firms that had been well-established in the housing industry for decades before entering HERS business. In the mid 1990s, only a few thousand HERS ratings had been processed for new and existing homes by HERS providers. However, since the late 1990s, these second-generation providers have accounted for most of the growth in the industry.

Second, there were more large builders in the 2000s than there were in the early 1990s when HERS first undertook a national effort, and these larger builders seem more willing and able to use HERS ratings. The largest 100 builders (over 500 housing units per year) were 37 times more likely to use HERS ratings on some of their newly constructed housing units in 2005 than the rest of the home construction industry.[105] The super-large builders (over 10,000 housing units per year) were 87 times more likely to use HERS ratings.

Third, the HERS Council and RESNET were able to continue the development of HERS ratings and link them with the EPA Energy Star program that has become a powerful national brand. They conducted further development of HERS and the HERS-Energy Star linkage, and made it cheaper and easier for

[105] Data from "Builder 100" rankings for 2004 by Builder Online (2005b) and from the EPA's Energy Star program (U.S. Environmental Protection Agency 2005b) were used for this calculation. Also, the U.S. Census Bureau.

builders to use, particularly large builders. A HERS rating of over 86 points out of 100 (which is 30% more energy efficient than MEC 92) qualifies a new home for an Energy Star label. The benefits to builders of the EPA program are, *first*, consumer recognition of the Energy Star label and, *second*, additional marketing tools, materials, and support. "Sixty-four percent of households recognize the ENERGY STAR label" according to Goldberg et al. (2005, ES-1) with a slight majority of households having a high understanding of what the label is meant to convey. This level of awareness and knowledge of the Energy Star label was generated through promotions by regional and local business and government partners for dozens of different kinds of products through "utility mailings or bill inserts, TV commercials, radio commercials, newspaper or magazine advertisements, and personal acquaintances" and additional EPA marketing (Goldberg et al. 2005, ES-2).

The Energy Star label has been available since 1995 via a HERS rating, but in the late 1990s it was made more user friendly for builders. After builders complained that third party HERS inspections added too much complexity and expense to the construction process, the EPA gave builders two additional options. First, the EPA would allow the use of the Energy Star label if 15% of a builder's homes were inspected and met Energy Star standards. Second, if builders verified energy efficiency using the Builder Option Package (BOP) checklists. Close to all new homes that qualify for Energy Star are qualified through HERS ratings or a sample of ratings, not a BOP. This is because qualification through ratings allows more flexibility in the design of homes (Plympton 2000; Harvey 2001).

Increased Importance of Second-Generation HERS Providers

By 2000, the second-generation HERS providers were increasingly important to the rating business, and by 2003 they were the dominant organizational force among providers. Most of the growth in the volume of HERS ratings can be directly attributed to the second-generation as show below in Table 10-8. Also, of the top 15 HERS providers that certified the most Energy Star homes in 2005,[106] all but one were

(2005) estimates that there were 88,700 general contractors in 2002 that built residential units.
[106] Data from U.S. Environmental Protection Agency (2005b) through September 2005.

2nd generation providers. The single 1st generation provider, CHEERS, certified the largest volume of Energy Star homes in 2005. Although this would seem to contradict the trend toward the importance of 2nd generation providers, there are two things that are unusual about California. First, state law in

Table 10-8. Growth in volume of HERS ratings by 2nd generation HERS providers

Year	Percent of HERS *providers* that were 2nd generation [c]	Percent of HERS *ratings* from 2nd generation providers [c]
1996	4%	< 1%[a]
2003	62%	70%[b]
2005	69%	85%[b]

[a] Calculated from data by Farhar et al. (1997).
[b] Measured by Energy Star certifications using data from U.S. Environmental Protection Agency (2003 and 2005b).
[c] Only HERS providers that had reported at least one certification of an Energy star home were included. HERS providers that started out as non-profits but later became for-profit were still regarded as 1st generation if they still placed an emphasis on advocacy as opposed to profit.

California required all HERS providers to be authorized by California Energy Commission. Until 2003, the Commission had not authorized any HERS providers other than CHEERS. Second, California has one of the largest new home markets in the country, and the unusual state law allowed CHEERS protection from competition in a very sizable marketplace until recently.

Organizational Capacities and Difficulties Experienced by First-Generation Providers

The first-generation HERS providers are defined as HERS organizations that are accredited HERS providers that have placed an emphasis on the advocacy of HERS rating systems and provide support and services for HERS raters instead of placing an emphasis on making a profit from HERS ratings. There has been some variation in how these first-generation HERS organizations have been structured, staffed their organization, and went about advocating HERS ratings. Nevertheless, the following are common characteristics. Many, but not all, of these first-generation providers started in the 1990s, and helped build the basic infrastructure for HERS ratings and EEMs. Overwhelming, the professional background of the individuals who founded and first staffed these HERS organizations was that of work in government, low-income weatherization programs, non-profits, and/or DSM programs (which was found in the 2003 survey of HERS providers). These HERS providers usually have been non-profits, government offices, or programs of government offices.[107] Most have relied heavily on subsidies to fund their advocacy and system building to make HERS and EEMs viable.

Most or all of them have taken a very fragmented approach to providing HERS ratings with little or no organizational integration into 1) the actual selling and conducting of HERS ratings, 2) construction and installation of HVAC and insulation, and/or 3) consulting, designing, or testing for the building industry. In particular, not being organizationally integrated with HERS ratings has made it more difficult for the first-generation to control and coordinate the process of selling, conducting HERS ratings, and generating market value for ratings.

Little capacity to control how raters marketed and sold ratings: With a few exceptions, the first-generation HERS providers adopted a model of using independent HERS raters to generate the ratings that they would process for a fee. HERS providers would help market ratings, but it was usually up to raters to actually find the people willing to pay for a rating (Farhar et al. 1992). While the use of independent raters saved them the upfront costs and risks associated with training and hiring well-qualified, professional staff with experience in the construction industry to perform ratings, it also resulted in many less qualified HERS raters and allowed the providers little control over many aspects of the rating process. Specifically, providers had little say over how raters went about selling ratings, to whom raters tried to sell ratings, and how raters generally interacted with the housing industry.

Most providers had one or more well-qualified professionals who would consistently generate ratings, but most also had dozens or even hundreds of raters that would conduct very few if any ratings. As commented by staff at a HERS organization, "there is a lot of variation in the quality of raters."

When interviewing builders, raters, and providers, it was common to hear complaints about the HERS raters. Many independent raters of the first-generation are " . . . folks wearing rainbow suspenders who don't understand the construction industry." "They expect to have customers handed to them . . . they

[107] Energy Efficient Homes of the Midwest is a for-profit company that is still considered a first-generation HERS provider. It was formed from an early non-profit and the founder, Mark Jansen, has been heavily involved in advocacy for HERS ratings and building the basic institutional and organizational structure for HERS and EEMs since the early 1990s. Energy and Environmental Ratings Alliance was formed as a for-profit company from the

don’t go out and look for customers to pay for ratings.” ”Many raters do not have much motivation.” “There are plenty of raters who have taken a course, become certified, and have yet to issue a single rating.” “A lot of the raters are a joke,” “some raters do really shoddy work.”

“Some raters think that all they should do is the rating, and what happens to the ratings afterwards is someone else’s job . . . they do nothing to generate economic value for the costumers of the ratings.” “All raters do not put in the extra effort. Just doing the rating is not enough . . . you have to help builders market their energy efficient product. You have to give them encouragement to make homes more energy efficient, and give them information on products, materials, and techniques.”

Of course, HERS providers do require that raters are trained and tested on the technical aspects of conducting HERS ratings and their ratings are routinely monitored for control (Residential Energy Services Network 2002). Overall, this training, testing, and quality control likely does a good job of ensuring the technical accuracy of ratings. However, it does little to ensure that raters have the skills and experience to integrate HERS ratings with the day-to-day activities of designing, building, and selling new construction within the rest of the relevant sociotechnical system.

It appears that HERS providers usually took as raters whoever was willing to pay for the training and could pass a technical proficiency exam. However, this gave HERS providers little control over the marketing skills, and specifically if their raters . . .

- had a working understanding of the residential housing industry and its needs,
- had a good reputation with builders,
- had skill at making sales, and
- were well networked with builders and other stakeholders.

There are people on the job market with these skills and work experience in the construction industry that could likely master a set of routines to market and sell ratings, or, even better, who have already mastered a set of individual routines from previous employment that could be adapted for selling and conducting

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beginning, but its focus has always been on providing advocacy for HERS ratings and support for raters.

HERS ratings and that place them in frequent contact with builders and other housing professionals. However, first-generation HERS providers had no dependable way to recruit and retain such professionals. They could not offer them the benefits of a salary while settling into a new job with an uncertain future as a rater. Individuals with the above qualities and work experience would be highly employable in many, more lucrative, less risky occupations.

Capacity to coordinate: The lack of control, in turn, made it difficult to coordinate any comprehensive marketing strategy in the field. For example, HERS providers had no way to ensure that the same production builder would not be approached and annoyed by three different “guys with rainbow suspenders” and the next production builder not approached by any.

Lack of a flexible source of funding: As noted, these HERS providers received most of their operating budgets from grants, and they had very little revenue from ratings and training that could be flexibly used for system building. It appears that most of these grants were for advertising and trainings about EEMs and HERS. Many grant givers do not give money to organizations to pay for salaries of those directly engaging in profit making activities.

Capacity for strategic planning and evaluation: As mentioned above, most HERS did not have a management structure that separated strategic from operational decision-making. Also, the professional background of most executive directors and program managers in HERS providers were from a non-profit advocacy and/or government services background, which likely created additional biases in favor of their current organizational model that stressed education, incentives, advocacy, and providing support services to encourage sociotechnical change. In the interviews of first-generation HERS providers, it was found that of the fifteen executives or program directors of first-generation HERS providers that were interviewed from twelve organizations/programs, ten of them had previous professional experience in low-income housing, weatherization programs, energy extension, non-profit management, or government. Four of them had professional experience in one of these areas and in the for-profit sector. Only one of them had professional experience solely in the for-profit sector.

As discussed in Chapter 3 and noted by Chandler and others, the professional backgrounds of top managers often influence the strategic choices that they make toward options in which they are the most familiar and comfortable, and generalist managers usually are less constrained. Generalists usually do not have a professional identity that is vested in specific sets of operational details and thus fewer biases toward the status quo (Chandler 1962; 1977; 1990; Fligstein 1990).

Organizational Capacities of the Second-Generation and Their Uses for System Building

The primary defining criteria of second-generation HERS organizations was that they had a focus on making profit over that of advocating for the use of HERS. They are called second-generation HERS providers because they were typically “spins offs” of the first-generation providers. After starting out as a rater for a first-generation HERS provider, they became their own HERS provider as a for-profit business venture.

Many of these second-generation HERS providers were closely affiliated with large, well-established firms in the residential housing industry either as departments, subsidiaries, divisions or owners. As shown in Table 10-9, three of the top fifteen second-generation HERS providers operated as offices, divisions, or as subsidiaries of Fortune 500 companies. Two of these were Masco and Weyerhaeuser Real Estate Development. Another was a subsidiary of Tempo—one of the largest installers of HVAC and insulation in the country. These three second-generation providers were extremely well connected and as established in the industry as for-profit organizations can get. Most of the remaining also appear to have been reasonably connected.

The organizational models of second-generation HERS providers allowed them more sophisticated and powerful capacities for system building. Even though their emphasis is more on profit than the first-generation HERS providers, the second-generation HERS providers are still very much system builders. The efforts by the management of these firms to establish internal organizational routines to sell and conduct HERS ratings might have saved the entire system-building effort for HERS and EEMs from financial ruin. Moreover, staff from these second-generation HERS providers are active on the board of

Table 10-9. Top 15 2nd generation HERS providers: Data is the volume of EPA Energy Star homes conducted during a 12-month period ending September 2003.

Name	**Number of Energy Star in 2003 (B)**	**Year business started**	**Began Energy Star (B)**	**Accredited Trainer (A)**	**Specialization (C)**	**Subsidiary/division of larger corporation**
Energy Sense, TX	9,040	1999	2001		Inspection, marketing, code compliance to builders & utilities.	Sub: Masco makes, sells & installs building products.
D.R. Wastchak, AZ	7,881		2001		Inspection, consulting, marketing services to builders & utilities.	Owner of Wastchak owns Inkwell & Superior Walls.
EIC Inc., PA	4,761		1996		Inspection, consulting, marketing, & contracting help for utilities & builders	
Guaranteed Watt Saver Systems, OK	4,212	1977	1997	2003	Inspection, testing, consulting, marketing help for builders & utilities.	
TexEnergy Solutions, TX[C]	4,000	2002	2002	2003	Inspection, testing, consulting, & marketing services	Sub: Tempo is a large HVAC & insulation contractor since 1966.
ConSol, CA	3,261	1981	2001		Code compliance assistance, consulting, & engineering.	
A-TEC Energy Corp, IA	2,944	1987	2001		Program, technical, and field services for utilities	
MaGrann Associates, NJ	2,830		1996		Consulting and engineering for builders.	
Williams Insulation, TX	2,625		2001		Not known	Sub: Masco makes, sells & installs building products.
Builders Choice Diagnostic Services, NV	2,362	1996	1998		Inspection, testing, code, consultation services.	
Thermo Scan Inspections, IN	2,132	1979	1997		Inspection, testing, & consultation services	
Conservation Services Group, MA	2,018		1996	2003	Consulting, marketing, & evaluations.	
Building Science Corporation, MA	1,970		1997		Architecture, building science, consulting services.	
Energy Inspectors, NV	1,952		2001		Inspection, testing, consulting services.	Div: Weyerhaeuser Real Estate Development.
DPIS Engineering, TX	1,344		2002		Engineering, consulting, & testing services to builders.	

[A] RESNET, September 2003
[B] EPA Energy Star, September 2003
[C] Companies' web pages and telephone interviews

directors of RESNET that is engaging the continual task of improving the overall institutional infrastructure for HERS and EEMs and further integrating it into the residential housing industry. In the year 2005, ten of the twenty-two board members at RESNET were from second-generation HERS providers, and this is one of the ways that they have contributed to the on-going system building process.

Capacity to generate flexible-to-use sources of financial resources: Many of these second-generation providers have been small or moderately sized innovative, successful firms looking for business opportunities, or very large firms with immense financial resources such as Masco and Weyerhaeuser Real Estate Development (Lycos Financial 2005) or Tempo. Thus, they probably have had rather easy access to investment capital to flexibly use for system building. One important investment they made, which appears to have been difficult for first-generation providers, was hiring and training well-qualified, professional staff to sell and conduct HERS ratings in-house.

Capacities for control: Prior to entering the HERS business, the large majority of the second-generation HERS raters appear to already have had well-developed organizational routines for control of the market demand through their marketing and/or sales staff within their management hierarchy. This included well-developed organizational routines to sell products and services to some of the largest builders in the housing industry. Since the 1980s and occasionally the 90s, most of these second-generation HERS raters (or their parent companies) specialized in the design and installation of HVAC systems and insulation, building inspections, architecture, engineering, contracting services, and/or assisting with code compliance in the residential housing industry. This clearly applies to the vast majority of the fifteen most successful second-generation providers in 2003 (see Table 10-6).[108] We do not know many of the details about the organizational routines for marketing and sales of the firms that became second-generation HERS organizations. However, from the descriptions of the products and services that they advertise on their web pages, decades of successfully offering these services and products, lists of staff and their positions, and lists of clients, they appear to have well-developed sets of

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[108] Specifically, this is measured by the volume of HERS ratings during the twelve-month period that ended in September 2003.

organizational routines for these tasks. Specifically, these routines would allow them to control how their products and services are offered, how they are provided, and the price of the services. These are things that first-generation providers could not well control through their independent raters.

By becoming HERS providers, these firms were pursuing a classic diversification strategy when they added HERS ratings to their mix of products and services. They did this by hiring apparently well-qualified professionals to work in-house as raters and training them in a set of routines to rate homes. Also, and most importantly, they integrated these routines into the existing routines for the sale and delivery of the rest of their products and services.[109] There is a well-established body of research that points to the economic benefits of diversification into similar products and services because synergies among similar products result in lower costs and increased sales, as discussed in Chapter 4. Likewise, when diversifying into a new product, the production and sale of that product can often be affordably built into existing routines to sell/provide an existing product, if the new product is similar to the existing products and requires similar equipment, staff, distribution networks, and customers. This appears to have been the case for second-generation HERS providers.

Also, second-generation HERS providers are particularly good at creating additional value for HERS ratings by offering these as part of an interrelated set of turn-key services, stated one of the first-generation HERS providers. Design work, code compliance assistance, and marketing services appear to be particularly important to turnkey packages of services. For a builder, a rating certificate that says a new home is energy efficient is by itself not worth much. However, if HERS professionals offer the additional service of marketing their energy efficient homes and linking their ratings with larger, well-known marketing efforts such as Energy Star, additional value can be created for HERS ratings. Also, through code compliance assistance, a HERS professional can create additional value for ratings. By using HERS ratings to meet energy codes, in some jurisdictions builders can receive a reduction in building permit fees while simultaneously allowing themselves more design options that would not be

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[109] This was learned from the survey of first and second-generation HERS providers and supplemented by information from their web pages.

available through using the old-fashion, prescriptive checklists to meet energy codes. Conversely, HERS ratings can be used to create additional value for the traditional services and products offered by these firms, such as designs for energy efficient homes and HVAC systems.

Perhaps the most important means of control have been the routines that offered easy access to builders, particularly the large production builders. Some of the largest builders in the country already had accounts with these organizations that would become second-generation providers, and routinely interacted with them in the marketplace. It took very little effort for the sales staff of these HERS providers to say, "hey . . . how about we do a few HERS ratings in addition to design work and assistance with code compliance?"

Baden (2002) agrees with this. In a study of the most successful Energy Star programs, he found that access to large production builders was one of the key determinants of success. Furthermore, the survey that I conducted of both first and second-generation HERS providers generated additional evidence that second-generation providers had better access to builders. Second-generation providers were involved in 38% more building trade associations and programs that would place them into direct contact with builders, 81% more of them said that they worked actively with these building trade associations, and 100% more of them named for-profit organizations and building trade associations as being particularly important for their rating activities, relative to staff of first-generation providers.

Organizational abilities of large production builders: The success of the second-generation HERS providers was not likely due to *only* their organizational capacities for system building. It also appears to have been due to the greater organizational abilities of the large production builders as well. According to Baden (2002), it was easier for large builders to take advantage of the EPA Energy Star program. For the EPA sampling protocol to be advantageous, he stated that "the builder must be a large production firm that is committed to total quality management" and have experience and knowledge at building energy efficient dwellings from "senior management to construction superintendents." In other words, a builder must have the organization, staff, and technical knowledge to consistently construct large volumes of energy efficient homes (Baden 2002, 21).

As discussed in Chapter 6, many or perhaps most builders and subcontractors simply do not have the technical expertise to routinely build energy-efficient dwellings. Nevertheless, a sizable portion of the largest builders appears to have these capabilities or is trying to develop them. For example, ten of the fifteen largest builders in 2005 were Building America partners (see Table 6-1). Also, large builders usually have more sophisticated marketing capabilities (also see Chapter 6) that would likely be better able to take advantage of the marketing resources offered by the Energy Star program.

Approximately 58% of all Energy Star ratings for new homes built by firms from the 100 largest builders United States have been accounted for in the twelve-month period ending in September 2005. The top ten largest in 2005 were all users of the Energy Star label (calculated from data by the U.S. Environmental Protection Agency 2005b).

- 21 of the largest 25 builders were Energy Star builders in 2005.
- 10 of the 26th to 50th largest builders were Energy Star Builders in 2005.
- 9 of the 51st to 75th of the largest builders were Energy Star Builders in 2005.
- 5 of the 76th to 100th of the largest builders were Energy Star Builders in 2005.

Restructuring of the first-generation HERS providers: The success of the second-generation HERS raters appears to have caused changes in some of the first-generation providers. Some have gone out of business or are on the verge of doing so, and others have changed their focus. During interviews, some of the first-generation providers acknowledged that the second-generation providers are better at selling HERS ratings than they are, and made a decision not to directly compete with them and instead focus on training HERS raters for their rater's license and training housing professionals such as builders about energy efficiency, HERS ratings, and EEMs.

In 1996 there were approximately 24 HERS providers (Whole House, This 1996) and 23 of them well fit the description of first-generation HERS providers. Twelve of these providers had terminated their HERS activity by 1996 and are no longer accredited by RESNET.[110] Many of these were government

[110] This was verified through the RESNET web page and interviews with industry participants (Residential Energy

programs. Some of these were Energy Rated Homes of Ohio, Energy Wise Homes of Illinois, and Washington State University Energy Program (Residential Energy Services Network 2005).

The remaining first-generation HERS providers are a mixed assortment. Some have been conducting more ratings since the surge in ratings by the second-generation of raters, and first-generation HERS providers have conducted considerably less. Those that have been conducting more ratings (i.e. certifying Energy-Star homes) in 2005 than they did in 2003 include California Home Energy Efficiency Rating System, Lincoln Electric System, Inc., Wisconsin Energy Conservation Corporation, and E-Star Colorado. Also, new non-profit and government HERS providers have emerged, but none are conducting ratings in a volume that rivals the vast majority of second-generation providers (U.S. Environmental protection Agency 2003).

Concluding remarks: Several sets of large structures that worked to the advantage of the participant-advocates for HERS ratings. *First*, using their management hierarchies and organizational routines to market and sell their existing products and services, a second-generation HERS providers were able to better control the market demand for HERS ratings by link ratings to the day to day activities of the industry. *Second*, Energy-Star has grown into a fairly major, national brand name to which HERS ratings have been institutionally linked. *Third*, the second-generation of HERS raters has been successful creating demand for ratings with most of the country's largest production builders and linking ratings with the marketing efforts and internal quality control.

Conclusion: Comparing experiences of EEMs and HERS

Building a permanent set of organizational capacities to engage in continuous system building seems to be important to the long-term success of sociotechnical innovations. In this regard, it is interesting to compare the participant advocacy of EEMs that was discussed in the first part of this chapter with that of HERS for existing housing discussed in the latter part. EEMs did not benefit from the same type and extent of sustained effort at the national level to continual engage in system building that HERS did over

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Services Network 2003).

the last 15 years. Most notably, it appears that the participant-advocates of EEMs were not able to construct a well-developed set of organizational routines to engage in continual R&D of the EEM product. Although the HUD advisory committee attempted to do so, it appears to have been poorly organized for the task. On the other hand, RESNET has a technical advisory committee made up of HERS professionals that have engaged in the continuous development of HERS rating systems and searching for new ways to integrate it with the rest of the housing industry and thus create more value for HERS ratings. One RESNET accomplishment was to link HERS ratings to the EPA Energy Star program. However, very little data was collected about the work of RESNET or about the HUD advisory.

Part IV

Chapter 11: Conclusion

This study started with the premise that changes in large-scale, complex, sociotechnical systems are fundamentally organizational processes. Moreover, many large-scale corporate organizations have been extremely effective controlling the direction and pace of technological change by shaping, building, and altering the larger sociotechnical system to support certain technologies. To better understand this process, an organization-based theory of system building was developed. In the case study of HERS and EEMs in Chapters 9 and 10, evidence was overall supportive of the thesis that *progressive advocates of alternative technology have lacked the organizational capacities for system-building activities that are necessary for successfully developing marketable products*. The proposition that EEMs would fail in the marketplace was mostly supported. However, HERS have achieved a significant amount of success since 2002. Although existence of that success did contradict the thesis, the organization-based theory of systems was reasonably able to explain that success.

In addition, a number of caveats needed to be offered and additional theory developed. Small organizations can be very inventive, but do not have the organizational capacities to be innovative enough to bring about system-wide transformations. Of course, large size does not guarantee effectiveness. However, larger organizations are more able to internally develop or acquire a larger, better developed set of organizational capacities for system building. If small organizations with limited capacities are to transform a system, they must gain significant access to large structures. The only two historically proven structures appear to be large-scale management hierarchies and associated capacities or widely and strongly held institutions. Networks of organizations do not appear to be a complete substitute for in-house capacities. To the extent that network arrangements can be a substitute, it appears the organizations of the network must have enough capacities to be meaningful network-participants and have the structures and routines to integrate their activities with other organizations.

Summary

It has long been known that if a new invention is to be widely used, it must be well integrated into the larger sociotechnical system and doing so typically requires adjustments to both the basic invention and the larger sociotechnical system (Hughes 1989). Some inventions require a process of systematic innovation in which extensive changes are needed in both the invention and the system. This was the case with the telephone and its system of tightly coupled parts. For systematic innovations such as the telephone within a tightly coupled system of wires, switches, relays, and other components, there are a very limited number of ways for that system to be structured and still support the use of that technology.

Organization-based theory of system building

In Chapter 3, this study made an original theoretical contribution to our understanding of how organizations engage in system building such as social or technical invention and innovation. The organizations that successfully engage in system building were theorized as having a well-developed set of five organizational capacities for system building. These were the capacities to

- collect and manage information about relevant parts of the system,
- control relevant parts of the system,
- centrally coordinate parts of the system,
- strategically evaluate, plan, and oversee system-building activities, and
- generate financial resources for system building.

The theoretical construct of organizational capacities is highly abstract. When these capacities appear in actual organizations, they are more concrete structures that range from management hierarchies to divisions, departments, offices, and day-to-day work routines. Theoretically, for the important technical and social parts of a system, there are sets of routines in one or more organizations for gaining information about, controlling, and coordinating these parts, and strategically planning how to coordinate changes among them as the system evolves.

For certain system-building activities such as radical, systematic innovations with tightly coupled parts of sociotechnical systems, it is theoretically very important for there to be a system-building organization or a network of organizations with a strong set(s) of capacities to evaluate, control, and coordinate the fit of the new invention into the sociotechnical system. These organizational capacities function to maintain existing systems arrangements, to fit new inventions into the system, and to control the direction and pace of change in that system. Theoretically, large, complex, centrally controlled organizations go hand-in-hand with large, complex, sociotechnical systems, and in theory without such organizations we would not have most of the sociotechnical systems that are equated with modernity.

Rarely is there a single organization that controls and coordinates the development of an entire sociotechnical system. Most often the development of sociotechnical systems is guided by a network of organizational system builders. However, the concept of networks does not have a prominent place in the theory developed in this study. Instead, networks are viewed as fundamentally an organizational phenomenon, and when the term is used to describe the relationship between two organizations it is meant to imply sets of organizational routines that cross over between the organizations and integrate their activities.

However, by the end of Chapter 3, this organization-based theory of system building was still too vague to be of much use in evaluating the thesis or for progressive advocates of technology to use. Part II of this study made use of an inductive approach to build the additional theory. Chapters 4 and 5 provided a valuable, more grounded understanding of the general dynamics that usually seem to accompany system-building activities, the various ways that organizational capacities manifest into actual organizational structures, and their uses for system building. A general theory was sought that contained an understanding of the basic organizational capacities for system building that could explain and predict success for any type or size of organization, although special consideration was given to its usefulness for participant-advocates of alternative technology.

Inductive approach to theory building through review of corporate organizations

Instead of summarizing Chapters 4 and 5 in terms of the history of corporate organizations, I want to distill some of the theoretical ideas that were induced through the review of these organizations and that appear to contribute to a general theory of system building. The dynamics of system building by corporate organizations include the five types of activities that are listed below. The process of system building does not necessarily proceed linearly through these categories, nor is it always characterized by each of them. These are:

1) building basic organizational structures,
2) building new parts for the existing system
3) rationalizing/reintegrating the parts of the existing system for improving control and coordination,
4) building organizational capacities that are specifically for system building, and
5) undergoing competitive and/or institutional isomorphic change where organizational capacities and other systems arrangements are adopted through networks of other system builders.

Each of these activities is described below in detail. However, for this study, building organizational capacities that are specifically for system building is by far the most important.

Basic organizational structures and routines: The original entrepreneurs/founders of an organization built the basic organizational structures, and these include a professional management hierarchy, routines for accounting, and generation of financial resources. As discussed in Chapter 4, these organizational structures allow for a basic set of organizational capacities to generate revenue, control and gain information, and coordinate activities both within and outside the organization. However, these organizational capacities are typically not very useful by themselves for system building, but are primarily to maintain the existing system and provide stability, not to control the pace and direction of sociotechnical change.

Building the basic parts of a new sociotechnical system: Organizations will often create new parts of the relevant sociotechnical system to support their core activities or the use of a new technology. These new parts of the system include additional new technologies, internal or external organizational structures such as marketing units, distribution facilities, consumer financing mechanisms and institutional arrangements such as laws and standards. The basic organizational structures and routines mentioned above do provide some ability to finance, create, control and coordinate these new parts. For example, even very simple management hierarchies can be used to locate a set of organizational routines to market a new product.

Integrating and re-integrating the parts of the system: Once the basic parts of the system have been constructed, organizations often attempt to rationalize and re-integrate these parts of the system to increase their control and coordination of them. This includes restructuring internal management hierarchies, or internalizing external organizational units into the hierarchy. Other times, they will divest organizational units to generate financial resources.

The above system-building activities are essentially that of constructing systems arrangements and then maintaining them with minor adjustments from time to time. As I explained in Chapters 3 and 4, organizational capacities for maintaining existing systems arrangements and are not very effective for dynamically adapting to or controlling sociotechnical change. To control or exert an influence on the direction and pace of sociotechnical change in a system, organizations need to construct a set of internal structures and routines that are specifically for system building.

Building organizational capacities for system building: As discussed in Chapter 5, organizations can develop structures and routines that are extremely powerful for controlling and coordinating the direction and pace of sociotechnical change. As described in Chapter 6, these routines are typically organized into the following.

1) *Strategically-focused central offices*: These have specific routines for strategic evaluation, planning, and oversight and have a significant degree of managerial isolation from the day-to-day operational details of an organization so as to minimize vested interests in the status quo of the organization.

2) Organizational routines to generate *financial resource*s and to *flexibly* allocate those resources for system building: Although external sources of investment capital were often available, retained earnings allowed flexibility when an organization had access to them. The routines to generate retained earnings were co-opted from production capabilities and managerial hierarchies of organizations. Also, the routines to flexibly allocate these resources were usually part of strategically focused offices.

3) Internal organizational structures to *shape and reshape specific parts of the sociotechnical system on an on-going basis*: These organizational structures include R&D labs, marketing units, offices of mergers and acquisitions, public relations offices, offices of government relations, and legal offices. With various degrees of sophistication, these internal structures are used to create new social and technical inventions, evaluate the fit of these with the system, and then adjust the fit. Out of these, R&D labs are some of the best-developed and sophisticated organizational structures for assessing and adjusting fit for new inventions. The research and development of Nylon was used as an example in Chapter 5.

Institutional isomorphic change: It was noted that there is not usually a single organization that controls an entire sociotechnical system, but instead a network of many organizational system builders. In which case, it is implausible for system-wide change to occur through the management hierarchy of a single organization. The other common mechanisms of spreading change through a system are competitive and institutional isomorphic change where specific system arrangements are adopted by other organizations through network relationships and, thus, become institutionalized. The spread of the multidivisional form, marketing departments, and centralized R&D labs are all examples of institutional isomorphic change.

Summarizing the theory from the inductive approach

In the above discussion of system-building activities, I mentioned various structures that were theorized to constitute some of the organizational capacities for system building and also some of the specific ways that these manifest in actual organizations. These are summarized:

- capacity to collect and manage *information* on the sociotechnical system
- capacity to *strategically evaluate, plan, and oversee* system-building efforts, which requires:
    - the allocation of time and resources for these strategic activities, and
    - the separation of strategic management from that of operational management
- capacity to obtain *financial resources for flexible use* for system building, which requires:
    - surplus financial resources, i.e. beyond what is needed to maintain existing systems arrangements,
    - financial control of part of a system, and
    - strategic flexibility to allocate resources with out external constraints
- capacity to *control* the parts of a system
- capacity to *coordinate* the relevant parts of the system.

However, the existence of capacities does not mean that an organization will intentionally use them for system building. They must first be recognized as capacities for system building by the organization before they can be used as such. One such example was the early industrial laboratories that could have been used for R&D of new products but instead were restricted to quality control and making incremental improvements in existing production processes for existing products. Such labs were not used for true R&D until there was a paradigm shift toward the recognition that technology could in fact be controlled.

Also, numerous instances were found where network relationships did not provide the control and coordination that organizations thought was necessary. Management hierarchies seem to usually do better. Thus, it was theorized that management hierarchies provide for more control and coordination. However, networks can often provide enough control and coordination to suffice, in particular because it can be very expensive to internalize parts of the sociotechnical system.

A rather important distinction was discovered between organizational capacities for system building and for maintaining existing systems relationships. For example, corporations can have a very effective set of structures and routines for maintaining existing systems arrangements that allows them to lucratively produce and sell their products and services, such as many of the large vertically and horizontally integrated, single product manufacturing firms of the late 1890s. However, these capacities can be almost useless for adapting to new situations and controlling the pace and direction of sociotechnical change. In fact, a very large percentage of these firms went bankrupt in the great depression of the 1930s largely because they could not adapt. However, firms that adapted specific capacities for system building were able to maintain or increase their profits during the depression.

Before this study moved to the case of HERS and EEMs, it analyzed the historical and contemporary organizational capacities of the residential housing industry, its ability to control the pace and direction of sociotechnical change, and characteristics of the industry in Chapters 6, 7, and 8. This was primarily to gain an understanding of the housing system to aid the case study in Chapters 9 and 10. Some additional theory was also developed.

The residential housing industry

As reviewed in Chapters 6, 7 and 8, it was useful to better understand the characteristics of the U.S. residential housing system. Historically, the technical and social characteristics of residential dwellings have made it less advantageous for the housing industry to invest in centralized mass production facilities and subsequently the industry has not developed the large, sophisticated management structures that are often associated with mass production for sale to mass market. In other industries, these more complicated management structures seem to be associated with organizational capacities for system building. Conversely, the history of the residential housing system has been of small firms with few organizational capacities for system building. For that matter, it has had relatively few capacities for maintaining existing system arrangements and to smoothly, efficiently construct residential dwellings.

Also, residential dwellings are a set of technical parts that must be fit together in a fairly precise way to maximize energy efficiency, durability, and safety for the occupants. Likewise, most technologies to increase energy efficiency of residential dwellings are usually highly systematic innovations requiring integration with tightly coupled technical and social parts of the housing system.

As would be predicted by the organization-based theory of system building, technological change in the housing industry overall has been rather slow, conservative, and has involved mostly autonomous innovations. Although the industry has made use of many new inventions, most of these have come from the manufacturers of construction inputs on the periphery of the industry, and have mostly been rather autonomous innovations, including new fasteners, coatings, engineered lumber, and prefabricated components requiring little change in how a home is designed, built, sold, and financed. Systematic innovations appear to have been much less frequent.

As described in Chapter 7, there are a few construction R&D labs run by government and non-profits on the periphery of the industry that produce a steady stream of inventions. However, the industry lacks the organizational capacities to integrate these inventions into the construction process. This seems primarily to be because the R&D labs are organizationally separate from residential builders. Moreover, builders lack the organizational capacities to control and coordinate their own construction process. They also appear to lack sets of routines that integrate their construction activities with activities of R&D labs through network relationships.

The R&D labs operated by manufacturers of construction inputs seem to be better at introducing their inventions into the market, probably because they have established market relationships with builders, although usually indirectly through local lumberyards. Also, the residential builders have at least some set of routines to choose, order, and receive construction inputs from manufacturers although, again, usually indirectly via local lumberyards.

There have been slow trends toward vertical and horizontal integration, more sophisticated management structures, and perhaps rudimentary organizational structures for R&D. However, the industry as a whole still lacks well-developed sets of organizational capacities for system building. The current industry is decentralized into mostly small firms that sell to local and regional markets. It is also an extreme case of fragmentation. The construction of new homes and sale of new and existing homes is conducted by dozens of different kinds of small, highly specialized firms such as those that focus on the purchasing of construction inputs, designing, building, selling, appraising, financing, and insuring of homes as well as the involvement of dozens of different subcontractors, each with their own specialization such as real estate attorneys, code officials, and title agents. In most other industries, a majority of the specialized tasks are integrated into single firms. The small size of most firms as well as the cyclic nature of the industry still makes it difficult for most builders to invest in R&D and marketing capabilities.

The existing housing industry presents a number of additional challenges and also some opportunities. A challenge is that legal control of 114 million residential units is spread out over roughly 80 million property owners/households that are organized into sets of domestic routines, not routines to facilitate technological change. This makes it unlikely that homebuyers and owners will be very proactive in technological change.

However, the process of financing and selling homes is a nexus of technological choices in which some policy makers have attempted “point of sale” (POS) inventions to influence the purchase of certain technologies with some local success. However, the organizational routines of a dozen or more firms involved in the sale of existing residential dwellings are tightly coupled to quickly and efficiently bring real estate transactions to completion. This makes some types of intervention problematic, particularly systematic innovations.

Also, additional theory was induced from Chapter 6. Specifically, a network of organizations will not be successful at system building unless the involved organizations have . . .

- the necessary sets of capacity for the particular system-building task, and
- these sets of capacity are well integrated among the organizations of the network.

For example, the network approach to control and coordination and occasional attempts at system building that dominates the housing industry appears to create significant difficulties for successfully introducing systematic innovations into the construction process. It is not a problem of generating inventions that are already quite abundant, but it is instead a problem of integrating them into the process of designing, constructing, marketing, selling, and financing residential dwellings. Construction firms typically lack the R&D units and analogous organizational structures that specialize in this process of innovation. There seems to be the perception that corporate R&D labs focus primarily on generating new inventions, but this is not true. Most corporations primarily use R&D labs to search for inventions by other organizations, evaluate the suitability of these inventions for its organization, and, if suitable, then integrate these inventions into their own organization and the larger system.

The case study of HERS and EEMs

Chapters 9 and 10 are a case study of participant-advocates of energy efficiency that invented HERS and EEMs as a new set of organizational and institutional arrangements to support the use of energy efficient technology, and then integrated these sociotechnical inventions into the U.S. residential housing system in the lower 48 states from the late 1970s through 2004. Specifically, the case study is an evaluation of the thesis that *too few organizational capacities for system building have been a reason why progressive advocates of alternative technology have not been more successful at developing marketable products.*

Chapter 9 took a national "bird's eye" point of view of the system-building process and attempted to identify the presence or lack of centralized organizational capacities to successfully integrate HERS and EEMs into the residential housing industry through a set of pilot projects and a study. Conversely, Chapter 10 looked at system building from the viewpoint of individual organizations at the community level.

As discussed in Chapter 10, the National Collaborative grew out of a network of HERS providers, the HERS Council and other organizational entities with a decentralized, network approach toward system building to support the use of HERS and EEMs and thus the use of energy efficient technology. This system-building effort was significantly assisted and structured by the financial resources and the pilot project/studies of the federal government. However, government was treated as a political actor instead of a system builder in this study.

The overall process to integrate HERS and EEMs into the U.S. residential housing industry at the national level was comparable to the generalized process discussed in Chapter 5 of integrating new social and/or technical inventions into a set of systems arrangements. Essentially, it was a process of evaluating the fit of the invention with the rest of the system, adjusting that fit, and engaging in subsequent iterations. However, it appears the system-builders lacked the organizational capacities to ensure that this process was successfully carried out. Specifically, it appears that there was not a set of organizational capacities to strategically evaluate, plan, and oversee system building, to exert enough control and coordinate the parts of the emerging system to set up an effective pilot project and study, to gain information about crucial activities in the emerging systems arrangements, to flexibly allocate finances where needed, and coordinate the timing of the expansion of the pilot project and use of EEMs and HERS to nation-wide.

Although government (via the DOE and FHA) had some of the capacities that were needed to finance, gather information about, and to control and coordinate the system building, it was not able to successfully engage these capacities. The government's involvement appeared to be heavily structured by political routines, instead of routines for system building. Also, while the HERS Council was eventually able to construct a set of standards for the HERS industry, it was too young, small, and lacking in resources to play a major role in other system-building activities.

The consequences range from minor to very significant problems. The lack of centralized organizational capacities seemed to only cause minor difficulty for setting up the basic organizational and institutional infrastructure for HERS and EEMs, probably because HERS organizations and stakeholders could agree on a basic agenda. However, where interests and needs diverge, the lack of centralized control and coordination caused problems, such as the natural gas industry's opposition to the national guidelines for HERS systems. Also, the pilot projects and study suffered from serious problems in strategic planning that included goals that were too broad and amorphous, too short of a time frame to evaluate and then adjust the fit, a misallocation of resources among implementation of the pilot and the pilot study, and a mismatch of research questions and policy goals. Other problems emerged from a lack of organizational routines to coordinate parts of the system when adjustments needed to be made such as adjusting the match between the demand for HERS ratings and funds to train HERS raters. Also, problems emerged because no organization had the centralized capacities to control and coordinate the various organizational parts of the system into an intraorganizational set of routines to collect data on the use of EEMs and HERS, and because of that there are also limited organized capacities for collecting information about the system.

By the latter half of the 1990s, HERS organizations were disappointed with the demand for EEMs, and this seems to have led to a rather arbitrary decision to switch from focusing on ratings for EEMs to that of focusing on HERS ratings for new homes. However, there never really was a well-planned, coordinated, and sustained effort to research and develop EEMs and ratings for existing homes into a workable set of products at the national level. However, given that EEMs and HERS ratings are highly systematic innovations in a rather tightly coupled set of systems arrangements, it likely would have been a challenging task even if a fuller set of organizational capacities for system building would have been available.

Chapter 10 is an analysis of individual HERS organizations using their capacities for system building at the local level. *First*, I compared and contrasted two different approaches to integrating EEMs into the residential housing system and used these to evaluate the above thesis; and, *second*, I used two different approaches to integrating HERS into the system to also compare and contrast and to similarly evaluate the thesis of this study.

The two different approaches to EEMs for *existing homes* are as follows. Most HERS organizations solicited subsidies for offering HERS ratings below market cost, advertised, and trained stakeholders. However, they did not have an effective set of routines to control or influence most mortgage brokers, loan officers, and realtors into using or even cooperating with the use of EEMs for existing homes. It appears that the benefits and incentives for using EEMs were neither substantial nor unique enough, and the use of EEMs did not fit well with the existing values and routines of the mortgage banking business. While some loan officers did use EEMs, this use did not appear to usually develop into a permanent set of organizational routines. Another, perhaps major problem was that most homeowners, mortgage lenders, secondary lenders, and other stakeholder organizations did not have the organizational capacities to be useful participants in a network with HERS organizations in this system building endeavor. In other words, even to the extent that stakeholder organizations wanted to help, they did not even have the capacities to control the day-to-day activities of their own small part of the industry well enough to help integrate EEMs into the larger sociotechnical system.

EEM facilitation was another approach to EEMs for existing homes. Instead of offering incentives and information in the hope that others will use EEMs and cope with the associated hassles of using them, facilitators were proactive and internalized much of the process of completing EEMs. They built the organizational capacities to control and coordinate the completion of EEMs and eliminated the associated hassles for industry participants. They established organizational routines that internalized many of the key tasks in the completion of EEMs for existing homes, including the coordination of the activities of housing professionals and homeowners.

However, these were primarily organizational routines to maintain existing systems arrangements—to complete EEMs. These were not for system building and they had a difficult time replicating these systems arrangements beyond northern California. Also, changes in the mortgage industry made EEM products less competitive, and these facilitators were too small of firms to have the organizational capacities to adapt through further system building, such as developing new, more competitive EEM products. Because of this, there are only a few firms that have remained in the EEM facilitation business and these are completing a smaller number of EEMs than before. EEM facilitation may soon vanish.

Of these two approaches, EEM facilitation was clearly the most successful at the local level by three criteria: 1) EEM facilitators as a group were responsible for as many if not more EEMs than most HERS providers on a per capita basis in their respective service areas, 2) EEM facilitation was responsible for verified energy efficiency improvements whereas most EEMs by HERS organizations did not appear to result in substantial improvements, and (3) For at least a decade, facilitators carried out a viable set of routines to lucratively complete EEMs without subsidies.

Comparing the two approaches: The relative success of EEM facilitators appears to have been in internalizing most of the activities involved in completing EEMs into a set of organizational routines to gain information, control, and coordinate the day-to-day activities involved in the completion of EEMs to remove most of the hassles and delays associated with EEMs. The approach of subsidies, advertisements, and training used by HERS organizations failed to create a durable set of organizational routines, and the reason appears to have been that neither the HERS organizations nor mortgage lending industry had the organizational capacities for controlling the day-to-day behavior of loan officers. The EEM facilitators did not face significant external constraints on how they used their financial resources for system building as did the HERS organizations, which seem to have allowed them more flexibility in building a set of organizational routines that actually worked.

However, even though EEM facilitators built a set of capacities to maintain existing systems arrangements, they failed to build a set of arrangements that would allow them to engage into continuous system building—to spread their organizational model nation-wide and to continue to develop EEMs so that their mortgage product could stay competitive in a changing housing industry. Although the HUD task force was created in 1993 to be a mechanism to improve EEM products among federal secondary lenders, it consisted of mid-level bureaucrats without real authority to act and does not appear to have made any significant improvements in federal mortgage products.

Second, the last part of Chapter 10 compared the effectiveness of the organizational capacities of first-generation and second-generation HERS providers that were targeting the new home market. *First generation providers* built the basic organizational and institutional infrastructure for HERS rating systems and have since remained focused on advocating for the use of HERS ratings and engaged in further system building. They were usually not managerially integrated into other parts of the HERS business and the housing industry, nor even into the actual selling and rating of homes. Thus, they engaged in system building by establishing network relationships, but this did not provide them with sufficient control and coordination to sell and conduct ratings in sufficient volumes. Just as with EEMs, they tried to rely on providing information and incentives in the hope that others would take the initiative to sell and use their services without much success. The *second-generation* became HERS providers as a profit-making venture, and have accounted for the large majority of growth in the volume of HERS ratings since the year 2001. While they seem to have been more focused on profit than the first-generation, they have also been involved in some important system building through their own organizations and also participate in system building through RESNET.

There are three primary reasons for the success of the second-generation HERS providers, and all large structures. *First*, the second-generation HERS providers were well-established firms in the building industry—including a few that were subsidiaries of Fortune 500 companies—doing work as contractors, subcontractors, designers, or consultants before they entered the HERS business. This gave them access to financial resources that could be flexibly used for system building and also much more sophisticated and diverse organizational structures. Other organizational structures and routines of the second-generation gave them greater control over market demand and allowed them to integrate HERS ratings with other parts of the housing system. The second generation used their own employees to conduct ratings, which gave them more control over how HERS ratings were sold and conducted. Also, they pursued a classic diversification strategy by integrating the selling of HERS ratings with their existing product and service to their existing customers in the housing industry. This gave them a greater ability to create additional value for HERS ratings by packaging them with their existing products and services, and, thus, integrating HERS ratings with a larger part of the housing system.

Second, there had been an increased number of large production builders over the last two decades, and these builders seem to have a greater ability to make use of and create value for HERS ratings and Energy Star labels. These large production builders had already been the customers of many of the second-generation HERS providers prior to the start of the HERS business. There are other likely reasons for the success of the second-generation. *Third*, the EPA Energy Star program was linked to HERS ratings, and has helped to institutionalize HERS ratings through a fairly powerful national brand name.

The factors that led to the linkage between the Energy Star program and HERS ratings: To one degree or another, the HERS Council and then RESNET were able to coordinate an effort to continually improve HERS ratings systems, and increase the integration of HERS ratings with the rest of the residential housing system. One of their successes was linking HERS ratings with the Energy Star label, and the efforts of the HERS Council and RESNET essentially constituted an R&D program for HERS ratings. They continuously evaluated the fit between HERS ratings and the rest of the system and readjusted the fit. However, relatively little data was collected on these activities of RESNET and the HERS Council.

Findings

The evidence from Chapter 9 clearly indicated that during the FHA and DOE pilot projects/study the lack of organizational capacities for system building at the national level was a source of serious problems in the effort to integrate HERS and EEMs into the U.S. residential housing system in the lower 48 states. Throughout the rest of the 1990s, the participant-advocates of HERS and EEMs struggled for organizational survival, and it appears the HERS and EEMs scaled up to the national marketplace much too fast while major problems remained unsolved. Although much of the basic organizational and institutional infrastructure was built during the pilot period, there was very little accomplished in terms of actually integrating this infrastructure into the nation-wide residential housing system. In fact, the organizational infrastructure began to fall apart as many HERS organizations were closing their doors and/or going bankrupt. This evidence supports the thesis of this study.

The evidence from Chapter 10 indicated that EEMs have largely failed to succeed in the marketplace. In the instance of EEM facilitators, although they built a set of organizational capacities for maintaining existing system arrangements, they never developed any significant capacities for system building that would allow them to adapt to a changing residential housing system. For HERS organizations that were promoting EEMs, their failure was caused by a lack of organizational capacities to control the day-to-day activities of loan officers and other stakeholder organizations and to thus create sets of organizational routines to smoothly and efficiently bring EEMs to completion.

However, the evidence from Chapter 10 regarding the first and second-generation HERS providers selling ratings for new construction is more nuanced. HERS providers achieved a significant amount of success since 2002 and now in 2006 they are on the cusp of a modest, system-wide transformation in how builders and homebuyers go about choosing technology that affects energy use. The existence of that success does contradict this study's thesis that explicitly stated progressive advocates of alternative technology would fail because of a lack of capacities for system building. However, their success does correspond to the development of new organizational capacities for maintaining the existing system and perhaps for system building as well. For many second-generation HERS providers, this involved strategic decision-making to co-opt existing management hierarchy and organizational structures to sell construction, engineering, and consulting services, also to be used for the selling and conducting of HERS ratings. Also, the central organizational office invested financial resources to internalize activities of both HERS raters and HERS providers. This is consistent with the theory behind the thesis.

Additional caveats to findings

Some of the factors contributing to the success of second-generation HERS providers were not due simply to their own system-building efforts. One factor appears to have been the system building by some of the large production builders who are the customers for a large share of the HERS ratings now being conducted. Over the last few decades, these large production builders have consolidated, integrated, and diversified into larger, more complex organizations that apparently have given them a greater ability to generate value for HERS ratings.

Also, it appears that the process by which some of the HERS *raters* became second-generation *providers* might not have been due to any conscious system-building effort by the first-generation providers. Indeed, during interviews, some of the HERS professionals from first-generation providers seemed unsure about how the second generation of HERS providers emerged and why they were successful. It is likely the case that institutional and/or competitive isomorphic change played a role, not just system building.

There were also instances where organizational capacities were present but did not lead to sociotechnical changes that could perhaps have been expected. Regarding HERS organizations that used subsidies, advertisements, and training sessions, it appears that other factors mediated the effectiveness of their organizational capacities to influence mortgage brokers and loan officers into using EEMs. One of these factors is the set of cultural meanings held by mortgage brokers and loan officers that was not consistent with the use of EEMs regardless of how information was conveyed to them. In this situation, it was not that the organizational capacities were not extensive enough, but instead that the capacities were not well matched to the particular system-building activities. Another factor, which was already mentioned, was that the mortgage brokers and other firms in the housing industry did not have their own well developed sets of organizational capacities to integrate the use of EEMs into their own daily activities.

Furthermore, just because there is a set of organizational routines that could be used for system building or easily adapted to use for system building, it does not mean that an organization will use them or adapt them to that use. Many factors are likely relevant. However, the one that stands out from the review of corporate system building was the paradigmatic belief that a particular organizational structure could, in fact, be used for system building. This also seems to apply to HERS and EEM participant-advocates. All or most of the first-generation HERS organizations had a very basic management hierarchy that would have allowed them to establish a set of routines to conduct HERS ratings in-house or to facilitate EEMs. However, very few tried to do so even after they saw the success that others were having. The data collected through the case study hints that many first-generation HERS providers held a paradigmatic view of their participant advocacy that prevented them from taking that step. They seem to hold a view of themselves as teachers and activists, and not as full participants in the residential housing industry. Indeed most of them were professionally from non-profit/social work/government services backgrounds. A founder of one of the first-generation HERS providers was asked why he did not hire in-house staff to conduct ratings, and he answered, “Because I don’t want to compete with the private sector.

I would rather teach someone to rate homes than do it myself. We built the infrastructure for HERS ratings. That's what we are good at."

Generalizability of the findings

At a high level of abstraction, there is good reason to believe that the findings in support of the thesis (and caveats to those findings) can be generalized to the system-building activities of other participant-advocates of alternative technology in both the residential housing system and other sociotechnical systems. The general concept of organizational capacities was demonstrated to apply to a wide range of organizations and sociotechnical systems in Chapters 3 through 9, and it should apply to other progressive system building efforts as well.

However, the most interesting and useful aspects of the organizational based theory of system building are the more concrete ways that organizational capacities manifest as specific organizational structures and routines for system building, the ways that these interact with other organizations in a network, and the types of innovations and sociotechnical systems for which they are needed. It is at this more concrete level that we should be cautious about generalizing. Although we should be comfortable with the theory that organizational capacities for system building are needed to successfully shape the direction and pace of technological change, we do not yet know enough about the specific characteristics of organizations and sociotechnical systems to generalize. The degree to which an innovation is systematic and a particular set of systems arrangements are tightly coupled is likely to greatly affect the type and extent of organizational capacities that are needed. However, the concepts of systematic and autonomous and tightly and loosely coupled systems arrangements are not understood enough to measure their underlying phenomena well enough to link them to sets of needed organizational capacities for successful system building.

Furthermore, the case study of system-building to support the use of HERS and EEMs was under the assumption that government was not significantly acting as a system builder. This situation is likely quite common. However, in those cases where government is clearly acting as a system builder because it is insulated from its normal political routines, the findings of this study should not be generalized.

Additional theorizing: small, young organizations and system building

One of the interesting issues that is suggested by the organization-based theory of system building, but has not yet been explicitly discussed, is the extent to which small organizations can be successful at system building. As mentioned, the extent and sophistication of organizational capacities that are needed for system building will theoretically depend on the extent to which an innovation is systematic, and the extent to which the relevant systems arrangements are tightly coupled. Because the size and age of an organization does place constraints on the extent and sophistication of capacities that are possible, small organizations will in theory have a great deal of trouble with highly systematic innovations and tightly coupled systems arrangements. We cannot expect a five-year-old small business to successfully engage in the same kind of R&D projects that DuPont can. This all seems quite reasonable, but is there anything else that we can say?

I argue that small, young organizations can play an important role in system building for nascent, emerging, and also for well-established sociotechnical systems. However, the role that they play will usually be rather limited to invention, instead of innovation. Theoretically, we should expect small, young organizations to be more inventive because we can also expect them to not be so heavily invested in the status quo of any given set of systems arrangements.

However, innovation appears to be a much more difficult process for small businesses. When inventions require that highly systematic innovations are made to very tightly coupled parts of a system to successfully bring a new product to the market, it can require an extremely large, sophisticated set of organizational capacities for strategic evaluation and planning, gathering information, and control and coordination of a very diverse set of parts within an emerging or established system. Small organizations are clearly at a disadvantage unless they can participate in a network with other system building organizations.

While system building through networks is a possibility for small organizations and it does frequently occur, there are clear limitations to this approach. The idea of joint ventures and collaboratives assumes that there will be other organizations that share similar goals and have complimentary capacities for system building, which may not be the case, especially for radical, high risk, system building endeavors. Also, Teece and Pisano (1998), Teece and Armour (1977), Teece (1988), and others have pointed out that it is typically very difficult at the beginning of a joint venture into an R&D project to specify and agree upon what the final product will be, the needs for staff training and capital investment, and the obligations of each organizational participant that need to occur to ensure success. Also, it is typically difficult to fairly share benefits and risk, and for each participant to protect their intellectual property and trade secrets while still working closely. When such uncertainties and difficulties are high, as they typically are, engaging in system building through network relationships is problematic if not sometimes entirely unfeasible.

None of this means that small, young organizations cannot make contributions to system building efforts, because they often do. The case study in Chapters 9 and 10 is an example where a network of small organizations has helped to bring the residential housing industry to the cusp of making some fundamental organizational and institutional changes in how it makes technological choices. However, it is theorized that for the efforts of small organizations to have system-wide success in large scale sociotechnical systems they will need to have access to large structures that are either institutional or organizational. Except for products and services that occupy small niche markets, system-wide success implies mass production, mass distribution, and mass marketing, and by definition these small system builders do not have their own organizational structures for this.

I theorize that there are only four general pathways for small organizations to gain access to large structures and thus achieve a system-wide transformative effect from their system-building activities. *First*, through internal organizational growth, small organizations can expand and integrate into mass production, mass distribution, and mass marketing. *Second*, the small firms can merge with or be acquired by larger organizations that already have access to mass production, distribution, and marketing.

Third, small firms can contract out to larger organizations for mass production, mass distribution and marketing. *Fourth*, other small organizations can adopt the systems arrangements of the organization with the initial invention/innovation through competitive or institutional isomorphic change. In this latter case, the large structure is a set of institutional arrangements.

In the first two pathways to system-wide change, it is not fully accurate to say that small organizations successfully transform the system, because they had to become large to do so. In the third, while the organization was able to maintain its small size, it was only able to bring about system-wide change through the largeness of other organizations. Thus, to say that small organizations can transform the system through such means is also deceptive. Only in the last scenario the system is transformed through truly small organizational structures, but that are linked together through commonly held institutional arrangements. An approximate example of this was the first-generation HERS organizations and their guidelines for uniform, voluntary HERS systems. However, to the extent that these HERS organizations are poised to have a system-wide transformative effect, it has been significantly because larger, more sophisticated organizations have joined their network.

However, depending on the nature of the sociotechnical system, pathways three and four may not preserve the small organizational structures over the intermediate or long term. If there is relatively little sociotechnological change in the industry, small firms without specific organizational capacities for controlling the pace and direction of sociotechnical change will not be at much of a disadvantage. If, however, the small organizations are operating in a lucrative market within a fast paced, competitive, highly dynamic sociotechnical system, it is theorized that at some point larger firms will enter the market seeking profit and drive out the smaller organizations. The larger firms will likely have greater organizational capacities including their ongoing R&D projects to bring new and improved products to the market with which the smaller firms cannot compete.

Identification of limitations, knowledge gaps, and work remaining

There are empirical gaps in our understanding of how system building occurs in general. There are also empirical gaps in our understanding of how participant-advocates of EEMs and HERS engage in system building in the residential housing industry. At various places in the case study, it appeared that more was occurring than just organizational system building and probably involved processes of competitive and institutional isomorphic change (DiMaggio and Powell 1983). Two of those places were the spread of first-generation HERS organizations and the emergence of the second generation of HERS organizations. A better empirical understanding of this aspect of HERS and EEMs would increase our knowledge about how system level change is occurring in the U.S. residential housing industry. Likewise, it would be interesting to understand how organizational system builders have affected or been affected by the decentralized processes of setting standards and conventions, and the formation of norms in the U.S. residential housing industry that are discussed by Shove (2003).

There are significant gaps in our empirical understanding about if, when, and how governmental entities can successfully act as system builders and how these affect system-building outcomes. In part because of the need to simplify the analysis, the assumption for this study was that government was not an organizational system builder in the lower 48 states, but was merely acting as a political organization that responded to and largely acted as a tool of its constituents. Although the limited amount of data that was reviewed seemed to support that assumption, more research would be useful to confirm or perhaps partly disaffirm it. Likewise, as mentioned in the discussion of methods in Chapter 2, the state government of Alaska was much more involved in the building of systems arrangements to support HERS and EEMs and was quite successful.

Very little data was collected on the organizational capacities of the HERS Council, RESNET, and the HUD task force to engage in the continual development of HERS and EEMs. It is known that all three were engaged in these activities with various degrees of success, and that the limited data appears to support the theoretical importance of building specific capacities for system building to engage in continuous invention and innovation. From this data it might be possible to generate theoretical insights into how government can be more effective as a system builder and how a network of very small, young, system-building organizations can form an effective R&D collaborative for continuous invention and innovation.

Implications for policy and program design

When formulating approaches for influencing sociotechnical change, policy makers and participant-advocates should consider organization-based system building as an option. For those that usually rely on utility bill inserts to educate the homeowner about energy efficiency, this will require a rather radical departure. For others, it may merely require a modest re-conceptualization of what they are currently doing. This subsection will summarize that approach—as a conceptual model, specific implications for both policy makers and participant-advocates, and then as a step-by-step process. An important aspect of organization-based system building is viewing organizational routines as the fundamental building blocks of sociotechnical systems.

Very simply, system building to successfully bring technologies to the marketplace is a process of building organizational routines and the necessary institutional structures to support that set of technologies. The challenge is, of course, to select feasible technologies, determine what routines are the most important, construct those routines, integrate those routines with the rest of the system, and decide what institutional arrangements are needed to support those organizational routines. Also, a well-developed set of organizational capacities is crucial to both constructing and integrating these organizational routines into the relevant sociotechnical system. Before these are discussed, the importance of organizational routines as the basic social building block is addressed.

If a particular technology is to be successfully introduced to the mass market and used system-wide, then the choices to purchase and use that technology, and other behaviors to support that purchase and use, must become routine components of the sociotechnical system. Moreover, it is important that these routines be organizational routines. Since organizations are responsible for a large majority of the technological choices in U.S. society (Stern and Arsonson 1984) and an even larger majority when households are included as organizations, the routines must be organizational routines if a transformative effect on the system is the goal.

Individual routine behavior and non-routine behaviors will usually not suffice to transform the system, (for example, see the discussion of loan officers and EEMs in Chapter 10). Routines, such as these, that are not durable, integrated parts of a sociotechnical system will not have a significant transformative effect on the relevant sociotechnical system. Individual, non-routine behaviors occur too infrequently to develop into practical knowledge, skills, and network contacts to be retained until the next occurrence of the behavior, and they are not an integrated, durable part of a system. While individual, routine behaviors can develop into a retainable set of practical knowledge, skills, and network contacts, these still lack the resources and support of a larger organization. Also, when the particular individuals retire, quit, or die, no one will take over that routine.

A fundamental problem is that many behaviors are not easy to create as organizational routines. Some situations involve sets of behaviors that occur so infrequently that there is no chance for these to ever develop into routines that can be proficiently carried out. Choosing energy-efficient technology as part of the process of purchasing new homes or retrofitting existing homes are examples. Also, sometimes sets of behaviors are either incompatible with or so vastly different from existing sets of organizational routines that it is very unlikely for those behaviors to ever become a durable set of routines within an organization. This was the case described for the tasks to complete EEMs for existing homes. Scheduling HERS raters, finding, coordinating, and overseeing competent contractors, choosing among energy efficient technology, use of technical terms, and completing mortgage paperwork is vastly different and in a few ways is incompatible with the domestic routines of most households.

In such situations, one of the few feasible alternatives for a system builder is for another organization to internalize some or all of these infrequent, obscure behaviors by creating a set of routines and hiring a professional who can become proficient at completing these. Simply passing new building codes or “time of sale” regulations is not a substitute, because the technological choices, finding, coordinating, and overseeing construction work, and arranging financing must still usually be competently done if there is to be compliance with those codes or regulations. Both HERS ratings systems and EEMs are an example of this as well.

It is, of course, more complicated than this. For these organizational routines to be a feasible and durable part of the sociotechnical system, they must be well integrated into that system. This can require a very complex and extensive set of additional organizational and institutional arrangements, which was the case for HERS and EEMs. When a homebuyer watches a contractor install new insulation and weather stripping into the existing home they just purchased, it might appear simple. However, if a HERS or EEM were used, there is an extensive, complex set of organizational and institutional arrangements that has been constructed over a 25 year period. It appears that most of the crucial new systems arrangements are usually needed on the supply side of sociotechnical systems.

To build a larger set of new organizational and institutional arrangements, organizations must have or acquire a set of capacities for system building that, if possible, are largely distinct from capacities to maintain the existing system. This, of course, has been the topic of the last ten chapters. Next are specific recommendations for participant-advocates and policy makers.

Participant-advocates: Building and acquiring capacities for system building is probably the most important but also difficult, time consuming, and expensive activity of system building. Toward these ends, participant-advocates should locate themselves in the center of the dominant economic institutions within their relevant sociotechnical system. Accordingly, organizations should participate in market activities and adopt dominant organizational forms to the greatest extent possible without compromising the core environmental or social values that they hold for the particular technology they are advocating. This is one of the best ways to build and acquire the organizational capacities to acquire information, to control, and to coordinate the key aspects of the sociotechnical system. Referring back to Chapters 4 and 5, the successful corporate system builder’s capacities for information, control, and coordination came from their vertical and horizontal integration into the various parts of the system.

Furthermore, small, young organizations of progressive participant-advocates or alternative technologies should keep in mind that in all likelihood they will need access to large structures to achieve system-wide transformation. One of these ways to achieve access to large structures is through convincing larger, more established corporate organizations to adopt their alternative business model and joining their network of system builders to produce and sell their alternative technologies. It appears that the processes of institutional and competitive isomorphism are most likely to occur and result in success for second and third-generation organizations, if the first-generation can project the impression of success by actually being successful. These institutional and competitive processes are perhaps not system building per se, but are arguably a desirable consequence of successful system building. Also, it is another reason for being a full participant in the core economic activities of the sociotechnical system and adopting a profit-oriented but more ecologically sustainable business model that other established corporation organizations can mimic, instead of merely advocating that the adoption of the business model from the periphery of the system. (See Appendix E for more specific recommendations for participant-advocates to follow when using organization-based system building to introduce a new technology to the market place.)

Participant-advocates will likely be inclined to turn to government for help. Indeed, it can be a powerful political/legal actor that can provide legitimacy and help to institutionalize the use of various technologies. However, typically government should not be relied upon for various organizational activities involved in system building, such as strategic planning and coordination, nor held accountable for even a basic commitment of resources, or to deploy its organizational resources on behalf of progressive participant-advocates of alternative technologies.

Policy makers and program administrators: State and federal governments have a massive set of organizational capacities, financial resources, and legitimated authority that can have a profound effect on system-building activities when it intervenes into them. However, its effort can sometimes be counter productive to the stated goals of its public policy. As theorized in Chapter 3 and exemplified in Chapter 9, most activities of government are structured by political routines instead of routines for successful system building where resources are given out to appease constituent groups, activities are timed according to political cycles, and the democratic process can paralyze timely decision-making and thus greatly hamper any prospect for well-coordinated responses to problems that arise during system building. These are problems that occurred in the case study when government participated in the organizational aspects of system building such as conducting evaluations, allocating financial resources, and strategic planning.

However, governments can be very effective at shaping institutions that can aid system-building efforts including laws, regulations, codes, voluntary standards, and the legitimacy it can bestow upon a set of system-building activities. This was supported by the case study on HERS and EEMs in Chapter 9 and research by proponents of ecological modernization (e.g., Mol 1995; Spaargaren 1996). When the DOE and HUD convened the *National Collaborative on Home Energy Rating Systems and Mortgage Incentives for Energy Efficiency* in 1991, the increased willingness of industry to cooperate with HERS and EEM participant-advocates and the increased media attention suggests the ability of the federal government to give legitimacy to HERS and EEMs. Furthermore, the EPA's successful Energy Star program is another example where the federal government can provide assistance to system builders through its ability to shape the legitimacy and awareness of institutional arrangements.

When the government does intervene into system-building activities, it is recommended that it keep these strengths and weaknesses in mind. It should perhaps focus on shaping institutions to benefit system builders that are working toward the public good, but it should be cautious about getting involved in the organizational details of system building. When it does get involved in the organizational activities of system building, it should attempt to use organizational structures that break out of the political routines that seem to hamper system-building activities. It needs to find structures that do not have a built-in bias to appease some or all constituents, but that minimizes constraints imposed upon how grant money is spent, are timely in its response to the funding needs of its recipients, and avoid arbitrary start up dates and deadlines that happen to coincide with election cycles.

In closing, while small organizations can play an important role in the system building process to bring alternative technologies to the mass market, the theory developed and the evidence found in this study suggests that they will not be successful unless they gain access to large structures, either organizational or institutional. This raises some implications that might be troubling to some readers. It suggests that, to be effective, perhaps the small organizations that advocate for alternative technology might need to adopt some of the hierarchical, less democratic, organizational structures of their larger corporate competitors. Nevertheless, there is still some reason for optimism by those who prefer more democratic, small-scale, local, organizations. Many of the structures that were identified might not necessarily require massive, inherently undemocratic organizational structures. It is reasonable that flexible funding sources, separation of strategic and operational management, and specific capacities for system building might sometimes be adaptable to smaller, more democratic, decentralized organizational structures. However, size and sophisticated managerial hierarchies are likely crucial to the success of many system-building activities. This study improves our understanding of the benefits of size, hierarchies, and organizational capacities for system building, and this can help participant-advocates of alternative technologies make informed choices about their internal organizational structures and how to use them for system building. With this improved understanding, participant-advocates have a better chance to successfully influence the pace and direction of sociotechnical change.

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Appendix A: 2000 Survey of Colorado E-Star Lenders and Data

The goal of this survey was to assess the extent to which Colorado, E-Star-trained, mortgage lenders had used energy efficient mortgages (EEMs), how they perceived and used EEMs, and problems that they faced. E-Star loan officers are loan officers who received training on EEMs sometime from 1995 to 1999 and volunteered to participate in the E-Star energy efficient mortgage program.

Methods

The survey consisted of telephone interviews of a random sample of 45 loan officers from a list of 141 E-star loan officers from across the State of Colorado that originated home mortgages. Exactly 25 individuals were reached and agreed to complete the survey. To become an E-Star lender, loan officers had to go through the E-Star training and then volunteer to be on the E-Star list of lenders. The training included information on energy efficiency, how to use EEMs, and the benefits of EEMs. A large percentage of the lenders that went through the training did not volunteer to become E-Star lenders, and it is not possible to generalize the survey results to these other loan officers in the state.

Interviews were conducted from June 22 to June 29, 2000. The cooperation rate was 96% with only one refusal. In addition to the interview questions that explicated asked (found in Appendix A), many other useful comments were obtained during the course of interview and at the end.

Use of EEMs by Loan Officers

Of the 25 loan officers in the sample, 64% offered energy mortgages to their clients at least once a year since their training, and 24% offered them 5 times or more per year since their training, and 16% offer 21 times. Of the 25 loan officers, 36% had originated one or more energy mortgages per year since their training, 8% had originated 5 or more, and 4% had originated 50 or more.

Loan officers that had originated at least one EEM were asked if they had made use of the FHA, VA, RD, and/or the FNMA EEM. Of the 25 individuals surveyed, 28% said they had originated one or more FNMA energy mortgages, 24% said they had originated one or more FHA energy mortgages, and 12%

had originated one or more VA and RD energy mortgage.

They were also asked if they have originated either energy efficient or energy improvement mortgages. Of the 9 loan officers that originated energy mortgages, 8 (88%) had originated one or more Energy Efficient Mortgages, and 6 (66%) had originated one or more Energy Improvement Mortgages.

Through an extrapolation from the sample of 25 loan officers to the total population of 141 E-Star loan officers, it is estimated that 470 EEMs per year have originated from the list of E-Star lenders in the State of Colorado in the last few years. This estimate does not include any EEMs that may have been originated by non-E-Star lenders.

Use of HERS ratings for EEMs

The loan officers were also asked how often they made use of HERS ratings for the EEMs that they originated vs. alternative ways to certify energy efficiency. Of the 9 that had originated energy mortgages, 4 of them (44%) stated that they always made use of HERS ratings; 3 of them (33%) said that they made use of HERS ratings less than half of the time; and 2 of them (22%) said they were unsure. However, even those loan officers that answered the question said they were somewhat unsure about their use of HERS ratings. Some said that they thought they recalled asking their appraiser to arrange a HERS rating. This suggests the importance of appraisers for the success of EEMs, although more research is needed to establish if this is true or not.

Reasons for not originating more EEMs

Questions 14 through 21 gave a series of “reasons why some loan officers may not (always) make use of Energy Mortgages.” Very surprisingly, when asked which reasons were important, only 24% of the 25 loan officers said that not enough “financial incentives” for them, their bank, or their clients was “very or somewhat important.” Also, 72% said that this reason was “somewhat unimportant” or “not important at all” for not originating energy mortgages.

Some of the loan officers indicated that other reasons were more important for not originating more EEMs. Of these other reasons, “too much extra hassle and paperwork” was said to be “very important” or “somewhat important” by 64% of the officers. The other reasons that followed were: “borrowers did not seem interested” with 44% saying “very important” or “somewhat important, “the process was too complicated” with 40%, “too long of an extra delay in processing time” with 32%; “borrowers thought the costs of HERS ratings were too high” with 28%; and “HERS raters were not available to certify energy efficiency” with 16%.

The officers were asked if there were any other reasons for not (always) originating EEMs. One of the most common reasons was that they forgot of EEMs as an option (it had often been two or three years since their E-Star training) which was mentioned by three officers. Another loan officer pointed out that they have 7 pages of different mortgage products that could be used, but they only use 5 to 10 on a regular basis. This suggests the importance of following up with lenders once they complete training, so the concept of energy efficient financing does not get forgotten or lost among other mortgage products.

Another general group of answers centered on the perception that there just was not much need for EEMs by their clients. More specific answers were that EEMs did not generate value for their clients or were not applicable to their situation (mentioned by three officers); that EEMs were “not necessary from a qualifying standpoint” with the “now very liberal qualifying ratios” (mentioned by two officers); that “not many energy efficient homes were available” (mentioned by one officer); that “most homes in Colorado Springs were already energy efficient” (mentioned by one officer); that “costs of energy to most people in Colorado were insignificant” (mentioned by one officer).

One loan officer mentioned that by the time he usually got involved in the loan process it was too late to easily do an EEM.

Another loan officer suggested that builders might get angry and stop making referrals to him if he suggested an EEM because of the extra hassle perceived to go along with energy efficiency by builders.

In reports by NREL and other organizations, it has been mentioned that the banking industry is somewhat leery of energy efficient technology and uncertain about the positive economic impact of EEMs on mortgage portfolios. Although the question was not explicitly asked to the loan officers in the sample, not a single officer offered the comment that they did not trust the technical or economic feasibility of energy efficiency as a reason for not using EEMs. Nor did a single loan officer say that energy efficiency does not increase home value or that it will not save homeowners money. While the some of the loan officers on the E-Star list could hold these criticisms of energy efficiency and EEMs, these criticisms do not appear to be a salient issue among the majority of them.

However, it should be noted that the loan officers that originated mortgages typically do not incur any significant risk from defaults. However, originating loan officers are only one component of the mortgage industry. The secondary mortgage market does incur risk from defaults, and it may have different attitudes toward the technical and economic benefits of energy efficiency.

Incentives for originating EEMs

There has been talk in the HERS industry about the 2% qualifying ratios not being enough of an incentive for EEMs. However, surprisingly, 44% of the loan officers in the sample said that the 2% stretch offered by EEMs was a “very or somewhat important” incentive for them as loan officers. Additional comments made by a few of them suggested that the 2% stretch is more important to them as loan officers that specialize in moderate to low-income borrowers with poor credit ratings.

Also, when asked about the importance of “homes rated as energy efficient being appraised at higher values” and “qualifying for larger loans,” 64% said that this was “very or somewhat important”.

Officers were also asked about hypothetical reductions in interest rates for EEMs, and the responses were very positive. Of 24 lenders, 66% said that a 1/4% reduction in interest rates would be a “very important” incentive for them, and an additional 20% said it would be a “somewhat important” incentive for them. If there was a 3/4% reduction in interest rates, 83% said it would be a very important incentive for them and an additional 12% said it would be a “somewhat important” incentive.

General Attitudes toward E-Star Training and EEMs in general

Although the loan officers were not asked specific questions about the training they received, a number of loan officers volunteered positive comments about the training as well as pragmatic remarks. For example, “The training was excellent, and I was disappointed that I could not use it more . . .The

EEMs were not often applicable to the situation of most of my clients given the extra hassle involved."

A couple lenders made the criticism that they did not receive enough training on how to market EEMs to individual borrowers.

Most of the lenders appeared to have had a positive attitude toward the training and the concept of energy mortgages as indicated by the willingness of most to remain on the E-star list. It could be suggested that lenders wanted to remain on the list just to get a few referrals even when they had no intention of originating an EEM to borrowers referred by E-Star. While this could be true of some lenders, that interpretation is not consistent with the rest of the data that suggested some intent to use EEMs. First, 64% of the lenders stated they offered EEMs to their clients at least once since the training, and 34% had originated at least one EEM. Second, the simple fact that 96% of the officers that were contacted were willing to participate in the survey suggests an interest in EEMs. A 96% cooperation rate is extremely good for a telephone survey, particularly for a population as busy as mortgage lenders at the end of the month while they were in the middle of closings. Also, the interviews were supposed to last 5 to 10 minutes, but a significant number of them turned into half-hour conversations about EEMs. Most of these talkative lenders had positive things to say about the concept of EEMs (even if they were not actively originating them) and took the time to give meaningful suggestions on how to improve them. Although there was a sizable fraction of the loan officers that were somewhat rushed in their answers and critical of the lack of incentives offered by EEMs, none of them commented that EEMs were fundamentally a bad idea.

Selected questions from the questionnaire and quantitative data

4. Does your lending institution officially have available Energy Efficient Mortgages and Energy Improvement Mortgages?

1.	Yes	84%
2.	No	8%
3.	Don't know	8%

5. Since your training, how many times (IN AN AVERAGE YEAR) have your clients asked you (yourself) for Energy Efficient Mortgages or Energy Improvement Mortgages?

1. NONE 68%
2. 1 TO 5 TIMES? 32%
3. 6 TO 10 TIMES? 0%
4. 11 TO 20 TIMES? 0%
5. 21 TO 30 TIMES? 0%
6. 31 TO 40 TIMES? 0%
7. 41 TO 50 TIMES? 0%
8. 50 OR MORE TIMES? 0%

6. Since your training, how many times (IN AN AVERAGE YEAR) have you (yourself) offered your clients Energy Efficient or Energy Improvement Mortgage?

1. NONE? 36%
2. 1 TO 5 TIMES? 40%
3. 6 TO 10 TIMES? 8%
4. 11 TO 20? 0%?????
5. 21 TO 30? 4%
6. 31 TO 40? 0%?????
7. 41 TO 50? 4%
8. 50 OR MORE? 8%

7. When you offer your clients an Energy Mortgage how often do they accept (IN THE AVERAGE YEAR). (Note: This question was only asked to loan officers that had offered an EEM to a client.)

1. ABOUT 75% TO 100% OF THE TIME 31%
2. ABOUT 50 TO 75% 0%
3. ABOUT 25% TO 50% OF THE TIME 6%
4. ABOUT 25% OR LESS 62%

8. Since your training, how many Energy Efficient and Energy Improvement Mortgages have you (yourself) made (IN AN AVERAGE YEAR)?

1. NONE 64%
2. BETWEEN 1 and 5 28%
3. BETWEEN 6 and 10 4%
4. BETWEEN 11 and 20 0%
5. BETWEEN 21 and 30 0%
6. BETWEEN 31 and 40 0%
7. BETWEEN 41 and 50 0%
8. 50 OR MORE 4%

9 through 12. There are a number of different kinds of energy mortgages. Have you made use of . . .

	None	EEMs	EIMs	Both
9. FHA	3	2	2	2
10. VA	6	3	0	0
11. RD	5	2	0	2
12. FNMA	2	6	1	0

13. When you have used Energy Efficient and Energy Improvement Mortgages, how often have you use HERS ratings to certify energy efficiency instead of an alternative way. Would say that you made use of HERS ratings . . .

1.	ALWAYS	44%
2.	MOST OF THE TIME	33%
3.	OVER HALF OF THE TIME	0%
4.	HALF OF THE TIME	0%
5.	LESS THAN HALF OF THE TIME	0%
6.	NEVER	0%
7.	Don't know	22%

Next, I am going to read you a list of reasons why loan officers may not (always) make use of Energy Mortgages. Please tell me how important of a reason each one has been for you to not (always) use Energy Mortgages.

14. The first is: There have not been enough financial incentives for you and your bank or your clients. Would you say this is a . . .

1.	VERY IMPORTANT REASON	12%
2.	SOMEWHAT IMPORTANT	12%
3.	SOMEWHAT UNIMPORTANT	20%
4.	NOT IMPORTANT AT ALL	52%
5.	DON'T KNOW	4%

15. There has been too much hassle and extra paperwork.

1.	VERY IMPORTANT REASON	20%
2.	SOMEWHAT IMPORTANT	36%
3.	SOMEWHAT UNIMPORTANT	16%
4.	NOT IMPORTANT AT ALL	20%
5.	DON'T KNOW	8%

16. There has been too long of an extra delay in processing time for loans.

1.	VERY IMPORTANT REASON	8%
2.	SOMEWHAT IMPORTANT	24%
3.	SOMEWHAT UNIMPORTANT	20%
4.	NOT IMPORTANT AT ALL	20%

17. Borrowers did not seem interested when offered an Energy Mortgage.

1.	VERY IMPORTANT REASON	20%
2.	SOMEWHAT IMPORTANT	24%
3.	SOMEWHAT UNIMPORTANT	20%
4.	NOT IMPORTANT AT ALL	24%
5.	DON'T KNOW	12%

18. The process was too complicated.

1.	VERY IMPORTANT REASON	8%
2.	SOMEWHAT IMPORTANT	32%
3.	SOMEWHAT UNIMPORTANT	20%
4.	NOT IMPORTANT AT ALL	28%

19. HERS raters were not available to certify energy efficiency.

1.	VERY IMPORTANT REASON	12%
2.	SOMEWHAT IMPORTANT	4%
3.	SOMEWHAT UNIMPORTANT	8%
4.	NOT IMPORTANT AT ALL	40%
5.	DON'T KNOW	36%

20. Borrowers thought the costs of HERS ratings were too high.

1.	VERY IMPORTANT REASON	4%
2.	SOMEWHAT IMPORTANT	24%
3.	SOMEWHAT UNIMPORTANT	12%
4.	NOT IMPORTANT AT ALL	28%
5.	DON'T KNOW	32%

21. Any other reason?

1.	Yes	56%
2.	No	44%

22. (What is that reason?)

23. How important of a reason has this been? (Note: This question was only asked to those that indicated there was another reason in question #22.).

1.	VERY IMPORTANT	77%
2.	SOMEWHAT IMPORTANT	15%
3.	SOMEWHAT UNIMPORTANT	0%
4.	NOT IMPORTANT	8%

24. Which of these reasons has been the most important for not (always) using Energy Mortgages?

1.	NOT ENOUGH FINANCIAL INCENTIVES	8%
2.	TOO MUCH HASSLE AND PAPERWORK	21%
3.	TOO LONG OF A DELAY IN PROCESSING TIMES	4%
4.	BORROWERS DID NOT SEEM INTERESTED	8%
5.	THE PROCESS WAS TOO COMPLICATED	0%
6.	HERS RATERS HAVE NOT ALWAYS BEEN AVAILABLE	0%
7.	BORROWERS THOUGHT THE COSTS OF HERS RATINGS WERE TOO HIGH	4%
8.	OTHER	50%
9.	Don't know	4%

25. Energy Efficient Mortgages allow a 2% stretch in the qualifying ratios. How important of an incentive is that to you as lender?

1.	VERY IMPORTANT	25%
2.	SOMEWHAT IMPORTANT	21%
3.	SOMEWHAT UNIMPORTANT	21%
4.	NOT IMPORTANT AT ALL	33%

27. Homes that are rated as energy efficient can be appraised at higher values, and lenders can make loans for larger sums. How important of an incentive is this to you as a lender?

1.	VERY IMPORTANT	28%
2.	SOMEWHAT IMPORTANT	36%
3.	SOMEWHAT UNIMPORTANT	4%
4.	NOT IMPORTANT AT ALL	24%
5.	Don't know	8%

28. If Energy Efficient and Energy Improvement Mortgages offered a 1/4% reduction in interest rates for your clients, would this encourage you to make (more) use of them?

1.	VERY LIKELY	66%
2.	SOMEWHAT LIKELY	21%
3.	SOMEWHAT UNLIKELY	8%
4.	NOT LIKELY AT ALL	0%
5.	Don't know	4%

29. If Energy Efficient and Energy Improvement Mortgages offered a 3/4% reduction in interest rates for your clients, would this encourage you to make (more) use of them?

1.	VERY LIKELY	83%
2.	SOMEWHAT LIKELY	12%
3.	SOMEWHAT UNLIKELY	0%
4.	NOT VERY LIKELY	0%
5.	Don't know	4%

30. Do you have any additional comments about Energy Mortgages or HERS ratings?

Appendix B: 2000 Survey of Vermont EEM lenders and Data

The goal of the survey was to assess the extent to which loan officers participating in the EEM program by Energy Rated Homes of Vermont had used energy efficient mortgages EEMs, how they perceived and used energy efficient mortgages (EEMs), and problems that they faced.

Methodology

The survey consisted of telephone interviews of a sample of 20 lenders who were reached by phone and who agreed to participate from an attempt to reach a population of 40 loan officers from across the State of Vermont. The population was comprised of loan officers that had completed an EEM using the facilitation services provided by Energy Rated Homes of Vermont. Interviews were conducted in August of 2000. The cooperation rate was 95% with one refusal.

Selected questions form the questionnaire and quantitative data

4. My first question: Does your bank have available energy efficient & energy improvement mortgages?

1. Yes	95%
2. No	5%

5. Since 1995, how many times IN AN AVERAGE YEAR have your clients asked you, YOURSELF, for an Energy Mortgage?

1. NONE	32%
2. 1 OR LESS TIMES	32%
3. 2 TO 3 TIMES	16%
4. 4 TO 5 TIMES	11%
5. 6 TO 10 TIMES	5%
6. 11 TO 20	0%
7. 21 TO 30	0%
8. 31 TO 40	0%
9. 41 TO 50	0%
10. 50 OR MORE	0%
11. Don’t know	5%

6. Since 1995, how many times (IN AN AVERAGE YEAR) have you, YOURSELF, offered your clients energy mortgages?

1.	NONE	16%
2.	1 OR LESS TIMES	26%
3.	2 TO 3 TIMES	21%
4.	4 TO 5 TIMES	11%
5.	6 TO 10 TIMES	11%
6.	11 TO 20	5%
7.	21 TO 30	5%
8.	31 TO 40	0%
9.	41 TO 50	5%
10.	50 OR MORE	0%

7. When you have offered your clients an energy mortgage what percent of the time do they accept IN THE AVERAGE YEAR?

1.	NONE	6%
2.	20% OR LESS	47%
3	21% TO 40% OF THE TIME	6%
4.	41% TO 60% OF THE TIME	18%
5.	61% TO 80% OF THE TIME	0%
6.	81% TO 100% OF THE TIME	12%
7.	Don’t know	12%

8. Since 1995, how many Energy Mortgages have you originated IN AN AVERAGE YEAR?

1.	NONE	26%
2.	1 or less	42%
3.	2 to 3	21%
4.	4 to 5	11%
5.	BETWEEN 6 and 10	0%
6.	BETWEEN 11 and 20	0%
7.	BETWEEN 21 and 30	0%
8.	BETWEEN 31 and 40	0%
9.	BETWEEN 41 and 50	0%
10.	51 OR MORE	0%

9. Since 1995, what percentage of the energy mortgages that you originated have been energy efficient mortgages? (These mortgages allow a 2% stretch for new and existing homes that are already energy efficient, in contrast to energy improvement mortgages that finance improvements in existing homes.)

1.	NONE	68%
2.	20% OR LESS	16%
3.	21% TO 40%	0%
4.	41% TO 60%	5%
5.	61% TO 80%	5%
6.	81% TO 100%	5%

10. Energy Rated Homes of Vermont offers an $800 Energy Improvement Mortgage Service that includes an energy rating on existing homes, collection of bids from contractors, contract management, and oversight. Has one or more of your customers used this service?

1.	Yes	84%
2.	No	16%

11. How satisfied did your clients seem with this service?

1.	VERY SATISFIED	50%
2.	SOMEWHAT SATISFIED	38%
3.	SOMEWHAT UNSATISFIED	6%
4.	VERY UNSATISFIED	6%

12. How fair of a price do you think $800 dollars is for this service?

1.	VERY FAIR	44%
2.	SOMEWHAT FAIR	38%
3.	SOMEWHAT UNFAIR	13%
4.	VERY UNFAIR	0%
5.	Don’t know	6%

13. Did you or your clients have any problems with this service? Can you recommend any solutions?

The next questions are about the reasons that loan officers use energy mortgages. I am going to read you a list of reasons and please tell me how important each of them is to you.

14. The first is: Energy efficient mortgages allow a 2% stretch in qualifying ratios. How important has this been for you to originated Energy Mortgages?

1.	VERY IMPORTANT	22%
2.	SOMEWHAT IMPORTANT	28%
3.	SOMEWHAT UNIMPORTANT	22%
4.	NOT AN IMPORTANT REASON AT ALL	28%

15. Homes that are rated as energy efficient often are appraised higher and have higher market values. How important has this been for you to originated Energy Mortgages?

1.	VERY IMPORTANT	11%
2.	SOMEWHAT IMPORTANT	33%
3.	SOMEWHAT UNIMPORTANT	22%
4.	NOT AN IMPORTANT REASON AT ALL	33%

16. VHFA’s YESS energy improvement mortgage offers an interest rate reduction. How important has this been for you to originated Energy Mortgages?

1.	VERY IMPORTANT	53%
2.	SOMEWHAT IMPORTANT	33%
3.	SOMEWHAT UNIMPORTANT	7%
4.	NOT AN IMPORTANT REASON AT ALL	7%

17. Energy mortgages can give lenders the opportunity to make new contacts with first-time homebuyers, builders, and Realtors. How important has this been for you to originated Energy Mortgages?

1.	VERY IMPORTANT	17%
2.	SOMEWHAT IMPORTANT	39%
3.	SOMEWHAT UNIMPORTANT	17%
4.	NOT AN IMPORTANT REASON AT ALL	28%

18. Energy mortgages promote social equality by helping lower-income people qualify. How important has this been for you to originated Energy Mortgages?

1.	VERY IMPORTANT	50%
2.	SOMEWHAT IMPORTANT	28%
3.	SOMEWHAT UNIMPORTANT	17%
4.	NOT AN IMPORTANT REASON AT ALL	6%

19. Energy mortgages help conserve our nation's resources by promoting energy efficiency. How important has this been for you to originated Energy Mortgages?

1.	VERY IMPORTANT	50%
2.	SOMEWHAT IMPORTANT	39%
3.	SOMEWHAT UNIMPORTANT	0%
4.	NOT AN IMPORTANT REASON AT ALL	11%

20. Do you have any other reasons for doing EMs?

21. How important has this other reason been?

1.	VERY IMPORTANT	100%
2.	SOMEWHAT IMPORTANT	0%
3.	SOMEWHAT UNIMPORTANT	0%
4.	NOT AN IMPORTANT REASON AT ALL	0%

22. Of all the reasons that I gave (and that you gave), which has been the most important to you for using energy mortgages? (I can read the choices back to you if you like.)

1.	THE 2% STRETCH.	11%
2.	HIGHER APPRAISED AND MARKET VALUES.	0%
3.	REDUCTION IN INTEREST RATES.	17%
4.	NETWORK WITH FIRST-TIME HOMEBUYERS AND BUILDERS AND REALTORS.	0%
5.	SOCIAL EQUITY.	17%
6.	ENERGY CONSERVATION.	11%
7.	Other	44%

Next, I am going to read you a list of reasons why loan officers may not always use Energy Mortgages. Please tell me how important each reason has been for you.

23. The first is: There have not been enough financial incentives for you and your bank or your clients. Would you say this has been a . . .

1.	VERY IMPORTANT REASON	5%
2.	SOMEWHAT IMPORTANT	11%
3.	SOMEWHAT UNIMPORTANT	21%
4.	NOT IMPORTANT AT ALL	58%
5.	Don't know	5%

24. There has been too much hassle and extra paperwork. Would you say this has been a . . .

1.	VERY IMPORTANT REASON	28%
2.	SOMEWHAT IMPORTANT	28%
3.	SOMEWHAT UNIMPORTANT	22%
4.	NOT IMPORTANT AT ALL	22%

25. For Energy Improvement Mortgages, the risks of not completing the improvements correctly, on time, and on budget has been too high. Would you say this has been a . . .

1. VERY IMPORTANT REASON 6%
2. SOMEWHAT IMPORTANT 18%
3. SOMEWHAT UNIMPORTANT 29%
4. NOT IMPORTANT AT ALL 41%
5. Don't know 6%

26. There has been too long of a delay in processing time for loans. Would you say this has been a

1. VERY IMPORTANT REASON 35%
2. SOMEWHAT IMPORTANT 35%
3. SOMEWHAT UNIMPORTANT 12%
4. NOT IMPORTANT AT ALL 18%

27. Borrowers did not seem interested when offered an Energy Mortgage. Would you say this has been a

1. VERY IMPORTANT REASON 12%
2. SOMEWHAT IMPORTANT35 35%
3. SOMEWHAT UNIMPORTANT 35%
4. NOT IMPORTANT AT ALL 18%

28. The process was too complicated. Would you say this has been a . . .

1. VERY IMPORTANT REASON 17%
2. SOMEWHAT IMPORTANT 44%
3. SOMEWHAT UNIMPORTANT 22%
4. NOT IMPORTANT AT ALL 17%

29. You forgot about energy mortgages as an option. Would you say this has been a . . .

1. VERY IMPORTANT REASON 12%
2. SOMEWHAT IMPORTANT 41%
3. SOMEWHAT UNIMPORTANT 24%
4. NOT IMPORTANT AT ALL 24%

30. You get involved too late in the process to do an EM, because realtors and builders do not mention them to buyers. Would you say this has been a . . .

1. VERY IMPORTANT REASON 13%
2. SOMEWHAT IMPORTANT 38%
3. SOMEWHAT UNIMPORTANT 38%
4. NOT IMPORTANT AT ALL 13%

31. Borrowers have thought the $350 cost of HERS ratings for NEW construction was too high. Would you say this has been a . . .

1. VERY IMPORTANT REASON 13%
2. SOMEWHAT IMPORTANT 44%
3. SOMEWHAT UNIMPORTANT 19%
4. NOT IMPORTANT AT ALL 13%
5. Don't know 13%

32. You do not have enough information about EMs. Would you say this has been a . . .

1. VERY IMPORTANT REASON 12%
2. SOMEWHAT IMPORTANT 24%
3. SOMEWHAT UNIMPORTANT 18%
4. NOT IMPORTANT AT ALL 47%

33. (What is that reason?)

34. How important of a reason has this been? (Of the five who offered another reason.)

1.	Very important	100%
2.	Somewhat important	0%
3.	Somewhat unimportant	0%
4.	Not important at all	0%

35. Of all of the reasons (you and) I gave, which has been the most important for not (always) using Energy Mortgages?

1.	Not enough financial incentives	0%
2.	Too much hassle and paperwork	12%
3.	Too high of risks	0%
4.	Too long of a delay in processing times	24%
5.	Borrowers did not seem interested	6%
6.	The process was too complicated	0%
7.	Forgot about EMs as an option	12%
8.	I get involved too late in the process	24%
9.	I do not have enough information about Ems	0%
10.	Borrowers thought the costs of HERS ratings were too high	6%
11.	Other	18%

The next questions are about how mortgage originators may make use of EMs.

36. Compared to other options, how useful have energy mortgages been to improve the efficiency of substandard homes so you can close deals? Would you say . . .

1.	VERY USEFUL	29%
2.	SOMEWHAT USEFUL	59%
3.	SOMEWHAT NOT USEFUL	12%
4.	NOT USEFUL AT ALL FOR THIS PURPOSE	0%

37. Compared to other options, how useful have EMs been to help home buyers qualify for a loan amount that they could not otherwise receive?

1.	VERY USEFUL	24%
2.	SOMEWHAT USEFUL	41%
3.	SOMEWHAT NOT USEFUL	24%
4.	NOT USEFUL AT ALL FOR THIS PURPOSE	12%

38. Are there any other ways that you make use of energy mortgages?

39. How useful have EMs been for this?

1.	VERY USEFUL	67%
2.	SOMEWHAT USEFUL	33%
3.	SOMEWHAT NOT USEFUL	0%
4.	NOT USEFUL AT ALL FOR THIS PURPOSE	0%

40. Next, if a borrower was having a hard time qualifying for a conventional mortgage, which mechanism would you prefer to use to close the deal in an average situation?

1.	THE USE OF A 2% STRETCH THROUGH AN ENERGY MORTGAGE	31%
2.	THE USE OF OTHER MORTGAGE PRODUCTS DESIGNED FOR LOWER INCOME/CREDIT-POOR BORROWERS	50%
3.	TRYING TO STRENGTHEN THE BORROWER'S CREDIT RATING	6%
4.	SOME OTHER WAY	13%

41. WHAT IS THAT OTHER WAY?

42. How familiar are you with the Vermont Energy Code that all new homes are required to meet?

1.	VERY FAMILIAR	6%
2.	SOMEWHAT FAMILIAR	47%
3.	SOMEWHAT UNFAMILIAR	35%
4.	VERY UNFAMILIAR	12%

43. How much liability do you perceive for your lending institution for underwriting mortgages that do not comply with the state energy code for new construction?

1.	CONSIDERABLE LIABILITY	6%
2.	SOME LIABILITY	29%
3.	A SMALL AMOUNT OF LIABILITY	24%
4.	NO LIABILITY AT ALL	24%
5.	Do not know	18%

44. What measure does your lending institution most typically take to ensure code compliance for new construction?

1.	REQUIRES A COPY OF THE RBES (RESIDENTIAL BUILDING ENERGY STANDARDS) CERTIFICATE	40%
2.	REQUIRES AN ENERGY RATING OF 82 POINTS OR MORE	0%
3.	OTHER	13%
4.	NOTHING	27%
5.	Don't know	20%

45. Do you have any additional comments about Energy Mortgages?

Next, I have a couple questions about your own area of specialization in the mortgage industry.

46. What percent of your own specialization is in the first-time home buyer market?

1.	NONE	0%
2.	LESS THAN 20%	29%
3.	21 TO 40%	35%
4.	41 TO 60%	18%
5.	61 TO 80%	12%
6.	81% TO 100%	6%

47. What number volume of mortgages did you originate in the average month during the last year?

1.	10 OR LESS	67%
2.	11 TO 20	33%
3.	21 TO 30	0%
4.	31 TO 50	0%
5.	51 TO 100	0%
6.	101 TO 200	0%
7.	201 OR MORE	0%

Appendix C: Telephone Questionnaire Administered to HERS Providers in Fall 2003

1. Is your organization a . . .
   a) Non-profit.
   b) Non-profit program/division
   c) For profit.
   d) For profit division
   e) State operated.
   g) State operated program..
   f) Program of a State/private organization
   h) Alliance

2. When was your organization (or program) founded?

3. Who founded the organization? (Organizations and/or individuals names? Contact info?).

4. How long have you been with the organization? What is your job title? Have you always been employed in the same capacity as now?

5. What is your professional background?
   a) Construction
   b) Banking
   c) Real state
   d) Appraising
   e) Business
   f) Low-income housing
   g) Weatherization
   h) Architecture
   i) Energy Extension
   j) Non-profit management
   k) Government
   l) Other

6. What are your primary program/activities that you use to promote EE in the residential housing industry? Which of your staff is responsible for each of these activities.
    a) Education and training of housing professionals (Which professionals?)
        ai) Raters.
        aii) Consumers.
        aiii) Builders.
        aiv) Subcontractors.
        av) Lenders.
        avi) Realtors.
        avii) Appraisers.
        aviii) Home Inspectors.
        aix) Code officials.
        ax) DOE low-income weatherization
    b) Operating a HERS system.
    c) Energy mortgages
    d) Energy codes
    e) Other_____________.

7. In addition to ratings, what other products and services does your organization sell?
    a) Code verification
    b) HVAC
    c) consulting
    d) insulation
    e) sealing
    f) training, such as???
    g) Code compliance strategies

8. How do you find customers for your ratings?

9.When you consider all your activities (HERS ratings, trainings, code work, and consumer education) would you say that your organization is
    a) Almost completely focused on existing housing.
    b) Mostly focused on existing housing.
    c) Evenly focused on both,
    d) More focus on new construction.
    e) Almost entirely focused on new construction.

10. How many full time employees (or FTEs) does your organization have? Could you please list the first names of your staff and indicate which are responsible for each of these above activities?

11.What terminology do you use to describe mortgages that promote energy efficiency? Explain?
    a) EFF?
    b) EMs?
    c) EEMS
    d) EEMS and EIMs?
    e) Other?

12.Which mortgage product do you advocate the hardest?
- a) FHA.
- b) FNMA
- c) VA
- d) RHA
- e) Other
- f) All advocated evenly.
- g) none

13.Does your state, or someone else offer their own energy mortgage in your service area? (How and what are the terms?)
- a) Yes
- b) No
- c) don't know

14.What do you do to encourage EMs? For new or existing housing?

15.(If facilitating EIMs was an answer above) Explain what you mean by facilitating EIMs? How did you get into facilitating EIMs? (How did you hear about it? Who trained you? When?)

16.(If not already mentioned) Have you ever considered the facilitation of EIMs like they conduct in Vermont and California?
- a) Yes (Explain)
- b) No (Explain)

17 Does anyone in your service area facilitate EIMs?

18. Does your organization own any subsidiary organizations?
- a) Yes (If so, what? ____)
- b) No.

19. Is your organization a subsidiary of any other organization?
- a) Yes (If so, what? __________________________________)
- b) No.
- c) part of a government entity

20. Is your organization(s) a member of a trade organizations, such as . . .
- a) RESNET
- b) ERHA
- c) NEHERS
- d) HBA
- e) State/local BA
- f) MBA
- g) EEBA
- h) ACEEE
- i) ACCA
- j) NASEO
- k) ASHRA (Sp?)
- l) Tex Hero

21. Which of these do you actively work with? And how?
   a) RESNET
   b) ERHA
   c) NEHERS
   d) HBA
   e) State Builders Association
   f) MBA
   g) EEBA
   h) ACEEE
   i) Air Conditioning Coalition of American
   j) NASEO
   k) ASHRA (Sp?)
   l) Tex Hero

22. Is anyone from your organization currently on the board or a committee at RESNET?
   a) Yes
   b) No

23. Have anyone ever been?
   a) Yes
   b) No

24. Do you work with PATH? What do you do with them?
   a) Yes.
   b) No.

25. Are there any other organizations that are particularly important to your activities and programs? (What are these organizations? What do they do? And how are you involved with them?)

Additional Screening Questions for (only) HERS Organizations

26. What is your service area? ____________________. (In theory or practically speaking?)

27. How many HERS ratings did process last year? __________.

28. How many active raters do you have?

29. How many of you raters are independent contractors ? How many are staff?
   a) Independent contractors?
   b) Staff?

30. Why?

31. What do you charge to process a HERS rating? _____________

32. What do your raters typically charge? ____________

33. Are these prices subsidized?
   a) Yes (Explain, by who, and how much?)
   b) No.

34. Are rebates offered on these prices?
    a) Yes (Explain, by who, and how much?)
    b) No.
    c) don't know

35. To the best of your knowledge, what percent of the ratings that you process are for . . .
    a) Existing housing.
    b) New housing.

36. Does your organization conduct BOP inspections?
    a) Yes (How many in the last 12 months?______________)
    b) No

37. In addition to a HERS certificate, do you give Energy Star labels for qualifying homes?
    a) Yes
    b) No

38. To the best of your knowledge, what percent of the ratings that you process are used for . . .
    a) EEMs.
    b) Code compliance
    c) Diagnostic work
    d) Certify new const
    e) Other.

39. Does your organization rate/inspect manufactured homes or military housing?
    a) Manufactured
    b) Military housing
    c) Both
    d) Neither

40. Do you conduct an initial rating from plans
    a) Yes
    b) No

41. Has this focus on _______ and _______changed over time?
    a) Yes (Explain) #
    b) No.

Appendix D: Interview Guide Administered to EEM Facilitators

1. Is your organization a . . .
   a) Non-profit.
   b) For profit.
   c) State operated office
   d) State operated Program
   e) Alliance
   f) Other.

2. When was your organization (or program) founded?

3. Who founded the organization? (Organizations and/or individuals names? Contact info?).

4. How long have you been with the organization? Your job title? How did you into this line of work?

5. Does your organization own any subsidiary organizations?
   a) Yes (If so, what?
   b) No.

6. Is your organization a subsidiary of any other organization?
   a) Yes (If so, what?)
   b) No.

7. What is your professional background?
   a) Construction
   b) Banking
   c) Real state
   d) Appraising
   e) Business
   f) Other

8. Is your organization primarily focused on increasing the energy efficiency of existing housing, new construction, or do you do significant work on both?
   a) Existing housing.
   b) New construction.
   c) Both (Explain).

9. What are your primary program/activities that you use to promote EE in the residential housing industry? Which of your staff is responsible for each of these activities.
    a) Education and training of housing professionals (Which professionals?)
        i) Builders.
        ii) Subcontractors.
        iii) Lenders.
        iv) Realtors.
        v) Appraisers.
        vi) Home Inspectors.
        vii) Code officials.
        viii) Other.
    b) Operating a HERS system.
    c) Facilitation of EIMs.
    d) Energy codes (encouraging acceptance, understanding, and compliance of them).
    e) Other____________.

10. Would many employees does your organization have?
    a) One
    b) Two
    c) Three
    d) Four
    e) Five
    f) Six
    g) Seven
    h) zero

11. Could you please list the first names of your staff and indicate which are responsible for each of these above activities?

12. What terminology do you use to describe mortgages that promote energy efficiency? Explain?
    a) EMs?
    b) EEMS and EIMs?
    c) EFF?
    d) Other?

13. Does your state, or someone else offer their own energy mortgage in your service area? (How and what are the terms?)

14. Which type of EMs do you facilitate?
    a) FHA (Percent of total_____).
    b) Fannie Mae (Percent of total_____).
    c) VHA (Percent of total_____).
    d) RHA (Percent of total_____).
    e) Other.

15. What is your service area? ___________ .

16. How many per year have you done? _______

17. What is your main source of customers for EIMs facilitation?
   a) Referrals from bankers.
   b) Referrals from realtors.
   c) Referrals from home inspectors.
   d) Home buyer call us up on their own . . . . (how to do they hear about you?).
   e) Other.

18. (How do you find bankers in which to network with and give you referrals?)

19. (How do you find realtors, home inspectors, or other sources of referrals?)

20. Do you pay for your referrals?
   a) Yes.
   b) No.

   21. If yes) How much? _______

   22. To whom? (Explain?)

23. Do you direct advertise to homeowners and buyers?
   a) Yes.
   b) No.

24. If yes (Money spent _______ per ________).

Loan officers

25. (If yes) Which of the following do you rely on the most heavily to educate lenders? (Please say yes to any that apply.)
   a) One-on-one training and assistance.
   b) Group trainings sessions.
   c) Sit in on meetings and explain the process of facilitation
   d) Targeted advertising.
   e) Web pages.
   f) Other?

26. What characteristics do you teach them to recognize in a borrower?
   a) If they are buying an old home (how old? ____).
   b) If it has serious energy deficiencies.
   c) An inefficient fuel source (electric, or, in some regions, gas).
   d) If they could use a reduction in interest rates (or another subsidy).
   e) Someone that might really need or want an incentive that the program offers.
   f) Homebuyers are purchasing a house for under the FHA borrowing limits.
   g) Other?___________________.

27. What other professionals does your business network with?
    a) Realtors, and how and what do you tell them? ____________
    b) Home inspectors, and how and what do you tell them?_________
    c) Appraisers, and how and what do you tell them?___________
    d) Others, and how and what do you tell them?_____________

Turnover

28. I am interested in the amount of turn over that there is with the loan officers that you work with. Would you say the average time they spend as loan officers is
    a) Less than 1 year.
    b) Between 1 and 2 years.
    c) Between 2 and 3 years.
    d) Between 3 and 4 years.
    e) Between 4 and 5 years.
    f) More than 5 years.

29. How about Realtors? Would you say their average time as realtors is?
    a) LESS THAN 1 YEAR.
    b) BETWEEN 1 AND 2 YEARS.
    c) BETWEEN 2 AND 3 YEARS.
    d) BETWEEN 3 AND 4 YEARS.
    e) BETWEEN 4 AND 5 YEARS.
    f) MORE THAN 5 YEARS.

30. How about appraisers? Would you say their average time as appraisers is?
    a) Less than 1 year.
    b) Between 1 and 2 years.
    c) Between 2 and 3 years.
    d) Between 3 and 4 years.
    e) Between 4 and 5 years.
    f) More than 5 years.

31. What about home inspectors?
    a) Less than 1 year.
    b) Between 1 and 2 years.
    c) Between 2 and 3 years.
    d) Between 3 and 4 years.
    e) Between 4 and 5 years.
    f) More than 5 years.

32. When you call homeowners up on the phone to talk to them about your facilitation services, what do you say to them? Are they hard to convince?

33. Who makes the initial site visit to houses (after you receive a lead).

34. What is done on this first visit?
    a) Rating.
    b) Complete data sheet.
    c) Other?

35. How many minutes per home do you spend trying to educate homeowners?
   a) None
   b) Less than 15 minutes
   c) 15 to 30 minutes
   d) 30 to 60 minutes
   e) 60 to 90 minutes
   f) 90 to 120 minutes

Contractors

36. How do you find contractors? (And which of these is the most frequent means?)
   a) Previously used contractors.
   b) Yellow pages.
   c) Ask homeowner if they know of any.
   d) Other?

37. What is the size of the companies that you use to install retrofits?

38. How difficult is it to find qualified contractors to make bids?
   a) Very difficult.
   b) Somewhat difficult.
   c) Somewhat not difficult.
   d) Not difficult at all.

Miscellaneous

39. How frequently do homeowners accept your cost benefit analysis and agree to finance your recommend additional amount for EE as part of an EIM?
   a) All of the time.
   b) Most of the time.
   c) A majority of the time.
   d) Sometimes.
   e) Never.

40. How frequently does the EEM process delay the closing date?
   a) All of the time.
   b) Most of the time.
   c) A majority of the time.
   d) Sometimes.
   e) Never.

   41. On average, by how much time did the EEM process delay the closing dates?
      a) 1 to 3 days
      b) 4 to 6 days
      c) 7 to 9 days
      d) 10 t 12 days
      e) Never

42. How often are the EE improvements done on schedule? _______________
   a) All of the time.
   b) Most of the time.
   c) A majority of the time.
   d) Sometimes.
   e) Never.

43. How often are the EE improve done on budget?
   a) ALL OF THE TIME.
   b) MOST OF THE TIME.
   c) A MAJORITY OF THE TIME.
   d) SOMETIMES.
   e) NEVER.

44. Do you conduct post-ratings?
   a) Yes.
   b) No.

   45. (If yes), how often do post ratings find something wrong?
      a) Less than 1% of the time.
      b) Between 2% and 5% of the time.
      c) Between 6% and 10% of the time.
      d) Between 11% and 20% of the time.
      e) More than 21% of the time.

46. Give me a common example of something that was found to be wrong during a post-rating. (How serious do you consider this these problems?)

Next is realtors

47. Have you tried to educate realtors about EIMs and encourage them to cooperate with the use of HERs?
   a) Yes
   b) No

   48. (If yes) Which of the following do you use to educate realtors? Please answer all that apply.

      a) One-on-one training and assistance.
      b) Group trainings sessions.
      c) Targeted advertising.
      d) Web pages.
      e) Other?

   49. (If trainings are used) Do you conduct your own trainings or do you contract out?
      a) Own trainings.
         i) On a routine basis? (Yes or No)
         ii) A single specialized person assigned the task? (Yes or No).
         b) Contract out (If so, with whom?).
         c) Both.

50. Do you offer continuing education credits to realtors for attending your training?
    a) Yes
    b) No

51. In which of the following ways do you frame the benefits of EIMs to realtors? (Please say yes to any that apply.)
    a) By explaining HERS as a marketing tool.
    b) By explaining EMs as a way to improve substandard housing and make sales.
    c) By explaining EMS as a way to qualify buyers for a loan.
    d) Other? _____________

52. When speaking to realtors about using HERS and EMs, do you make appeals to their concerns for (Please say yes to any that apply.)
    a) Economic equity.
    b) By appealing to values for economic equity.
    c) By appealing to values for the environment.
    d) Other? _____________ .

53. Do you or others in your service area offer financial incentives to realtors to encourage the use of HERS and/or EMS?
    a) Yes (Explain. $____ From who ______.)
    b) No.

54. Other ways of influencing realtors?

55. Any indication of how successful you have been to change the behavior and attitudes of realtors?

Next is appraisers

56. Have you tried to influence the way appraisers attribute value to energy efficiency in the real estate market?
    a) Yes. _________
    b) No.

57. (If yes) What solution did you work out?

58. Which of the following do you rely upon to educate appraisers? (Please answer all that apply.)
    a) One-on-one training and assistance.
    b) Group trainings sessions.
    c) Targeted advertising.
    d) Web pages.
    e) Other?

59. (If trainings are used) Do you conduct your own trainings of appraisers or do you contract out?
    a) Own trainings.
        i) On a routine basis? (Yes or No)
        ii) A single specialized person assigned the task? (Yes or No)
    b) Contract out (If so, with whom?).
    c) Both.

60. Do you or others offer continuing education credits to appraisers for attending training sessions.
    a) Yes
    b) No

61. Did you appeal to their concerns for
    a) Economic equity?
    b) The environment?
    c) Other? ___________

62. Any indication of how successful you have been?

Next is home inspectors:

63. Have you tried to influence the way home inspectors diagnose energy inefficiency and recommend improvements?
    a) Yes.
    b) No.

64. (If yes) Which of the following do you rely upon to train home inspectors? (Please answer all that apply.)
    a) One-On-One Trainng And Assitance.
    b) Group Trainings Sessions.
    c) Targeted Advertising.
    d) Web Pages.
    e) Other?

65. (If trainings are used) Do you conduct your own trainings of home inspectors or do you contract out?
    a) Own trainings.
    i) On a routine basis? (Yes or No)
    ii) A single specialized person assigned the task? (Yes or No)
    b) Contract out (If so, with whom?).
    c) Both.

66. Do you or others offer continuing education credits to appraisers for attending training sessions.
    a) Yes
    b) No

67. Did you appeal to their concerns for
    a) Economic Equity?
    b) The Environment?
    c) Other? ___________

68. Are they other ways you influence appraisers?

69. Any indication of how successful you have been?

Next, about the government

70. In an average year, how much of your own time is devoted to lobbying the state and federal government or otherwise trying to get them to change their laws, rules, and policies?
    a) None
    b) Less than 1%
    c) Between 2 And 5%
    d) Between 6 And 10%
    e) Between 11 And 20%
    f) Between 21 And 30%
    g) Between 31 And 40%
    h) Between 41 And 50%
    i) More Than 50%

71. Do any other staff members devote time to lobbying the state and federal government or otherwise trying to get them to change their laws, rules, and policies?
    a) Yes
    b) No

    72. (If yes) How many?
    73. What percent of their time is spent on this?
    74. (If yes to either #93 or #94) Is this lobbying a routine activity for your organization or do you only do it as issues come up.
        a) Routine.
        b) As issues come up.

Strategic planning and evaluation?

Small organizations often have a problem juggling the management of day-to-day activities with that of long-term planning. Some don't have the time to do both, so they ignore long turn planning and organizational growth. Some managed to do both.

75. How much overall time do you spend all these long-term strategic planning and organization building activities together. Again, I am not talking about managing and participating in the day-to-day and routine activities associated with _________________,
    a) Zero % of your time on long-term planning and organization building and all your time is spent on managing and engaging in the day-to-day and other routine activities of the organization.
    b) 10% on long-term planning and organization building and 90% on day-to-day and routine activities.
    c) 20% on long-term planning and organization building and 80% on day-to-day and routine activities.
    d) 30% on long-term planning and organization building and 70% on day-to-day and routine activities.
    e) 40% on long-term planning and organization building and 60% on day-to-day and routine activities.
    f) 50% on long-term planning and organization building and 40% on day-to-day and routine activities.
    g) 60% on long-term planning and organization building and 40% on day-to-day and routine activities.
    h) 70% on long-term planning and organization building and 30% on day-to-day and routine activities.

i) 80% on long-term planning and organization building and 20% on day-to-day and routine activities.
j) 90% on long-term planning and organization building and 10% on day-to-day and routine activities.
k) 100% of your work day is spent on long-term planning and organization building and others manage and engage in the day-to-day and routine activities of the organization.

76. Is it the specific job duty of a staff person to engage in long-term strategic planning and organization building OR do you only engage in it in an ad hoc manner. Would you say that you
   a) Most of the time it has been because of someone's job duty.
   b) Over half of the time
   c) Under half of the time
   d) Little of it
   e) None of it

77. How difficult is it for you as the executive director (manager) to FIND THE TIME to engage in long-term strategic planning and organization building? Would you say it is . . .
   a) Very difficult.
   b) Somewhat difficult.
   c) Somewhat not difficult.
   d) Not difficult.

78. How important do you think it is to find TIME to engage in long-term strategic planning and organization building.
   a) Very important.
   b) Somewhat important.
   c) Somewhat unimportant.
   d) Very unimportant.

79. Has it been difficult to take the next step with your ideas for the future—to take the time to and work out the nuts and bolts details and actually implement them?
   a) Very difficult.
   b) Somewhat difficult.
   c) Somewhat not difficult.
   d) Not difficult.

Grants, subsidies, and donations

80. Have you receive any grants and subsidies?
   a) Yes
   b) No

   81. Over the last ____ years, approximately what percent of your organization's average annual income was from

   a) selling services and products?
   b) . . . from Grants, subsidies, donations?
   c) . . . other _________

82. What are a few of your organization's largest UNMET financial needs?

83. Have you ever had what you thought was a creative new idea for your organization/business, but did not where to find money to get it started?
    a) Yes (please explain).
    b) No.

84. Often grants, donations, and subsidies come with RESTRICTIONS on how they can be used. Have you able to use money from these sources where you think your organization needs it the most, or have you often felt restricted and that there was a better way to
    a) Been able to use as needed.
    b) Thought there were better ways.

85. Overall, how restricted have you felt the available grant money has been? Would you say
    a) very restricted.
    b) somewhat restricted.
    c) somewhat not restricted.
    d) not restricted.

CORDINATION

86. Do you feel that the efforts of the industry actors to promote EE with HERS and EMs is well coordinate or could it be better coordinate? (Who coordinates activities in each state? Is there a unified program? Each industry actor doing their own thing?

ORGANIZATIONAL DIVISION OF LABOR QUESTIONS

87. Who makes the initial call to the homeowner? _____________

88. Who does the ratings? _____________

89. Who works with lenders and realtors? _____________

90. Who works with the contractors? ________________

91. Who does all the office paper work? _______________

92. Who takes responsibility to make sure that the contracting is done on time, on budget, and correctly? (Explain please)
    a) You the facilitator.
    b) The banker.
    c) Both you and the banker.
    d) Other.

FEES, REBATES, AND SUBSIDIES

94. What do you charge for your facilitation services?________ For just the rating _____?

95. Who pays the rating part of your fee?
    a) Homebuyers pay out of their pocket.
    b) It is just combined with the overall bill and is financed as part of EE improvements.
    c) Homebuyers finance them through the EMs.
    d) Contractors pay referral fees.
    e) Other.

96. Is the rating part of the fee subsidized or rebated?
    a) No.
    b) Subsidized. (How much? ______ Explain. __________).
    c) Rebated (How much? ______ Explain. __________).

97. Who pays the facilitation part of the fee?
    a) Homebuyers pay out of their pocket.
    b) It is just combined with the overall bill and is financed as part of EE improvements.
    c) Homebuyers finance them through the EMs.
    d) Contractors pay referral fees.
    e) Other.

98. Is the facilitation part of your fee subsidized and/or rebated?
    a) No.
    b) Subsidized. (How much? ______ Explain. __________).
    c) Rebated (How much? ______ Explain. __________).

HOUSING TECHNOLOGY (existing homes)

99. What energy improvements do you usually see as result of EIMS?

100. What improvements do you most commonly see made in existing houses because of recommendations from yourself and other HERS raters?

101. What are some of the more radical technology that you see?

102. What percent of the homes retrofit with these?

POINTS OF RESISTANCE AND SYSTEM BUILDING

103. What is the number-one, most difficult part of the facilitation process?

104. How do you address that problem?

105. What is the second most difficult thing about the facilitation process?

106. How do you address that problem?

107. What is the third most difficult thing about the facilitation process?

108. How do you address that problem?

109. Other problems and solutions?

Appendix E: Recommendations for Participant-Advocates Engaged in System Building to introduce a new technology

Much of the process of system building can be reduced to the simple, general, heuristic of identifying exactly where in a system that a technical invention needs to be introduced and specifically for what use, assessing the fit between the invention and the larger system, and adjusting that fit including the introduction of additional social and technical parts to support the use of that primary invention. However, particularly for small, young organizations, the most difficult and expensive part of the process will be to create the organizational structures and routines to engage in system building. This includes the routines and structures to flexible finance system building; strategic capacities for evaluation, planning and oversight of the process; and also the specific organizational routines to collect information on key parts of the system to be reshaped and routines for controlling and coordinating that fit.

The chances of success at system building can likely be increased by following the below recommendations that are based on past studies on sociotechnical systems, the review of corporate organizations and system building, and the results of the case study on HERS and EEMs. However, before these recommendations are discussed, a few caveats are needed. There is no single approach to system building will work for all situations, and the below recommendations are written with a particular set of conditions in mind. It is assumed that the goal is to introduce a social or technical invention into the market place as a new product that is an alternative to an existing product within the relevant sociotechnical system. Also, it is assumed that the builders are progressive, participant advocates with relative few organizational capacities who will need to rely more on network relationships for access to organizational capacities instead of internalizing these capacities into their management hierarchies.

Upfront planning and evaluation of the existing systems arrangements will increase the chances of achieving success as quickly and inexpensively as possible. Strategic planning and evaluation should preferably be conducted by individuals with a generalist's knowledge of the particular sociotechnical system, little no vested interests in the existing system, and a separation from the day-to-day management of that system. Furthermore, an organizational system builder must have a very good understanding of the basic invention and the relevant sociotechnical system.

The most important decision is likely to be determining a very specific end-goal for the system-building effort, which should be success in a specific market that is feasible to penetrate within the given timeframe, the current state of the invention and sociotechnical system, budget, and of course the available organizational capacities. Small, simple, and local are good market goals when starting out. In the initial stages, the objective is to gain a small foot-hold in the existing system from which to launch additional system building. It is not to immediately transform the entire system. The use of objective criteria for selecting an end-goal is recommended. Closely connected to the goal setting process, there should be an analysis of what the system-building effort is likely to entail including an analysis of the existing parts of the system that can be used to support the new invention, parts that must be adjusted, and parts that must be built anew.

I. Goal: Determine a narrowly-defined end-goal according to objective criteria.
    A. how autonomous is the innovation,
    B. how tightly coupled are the relevant parts of the system,
    C. if the innovation that can be affordably pilot tested on a small scale,
    D. how large is the potential market demand,
    E. existing organizations can make a firm commitment lend their capacities to assist,
    F. existing organizations will not resist the system-building effort, and
    G. can the project be complete within the available budget.
II. Assessment: Determine the extent and kind of adjustments in the invention and larger system that are likely to be needed to integrate that invention with the larger system.
    A. Assess the initial fit and the adjustments that will be needed for each major part of the system.
        1. Parts that can be used in current form.
        2. Parts that can be used if adjusted.
        3. New parts that must be built.

a. Production facilities.

b. Laws, regulations, and codes.

c. Distribution.

d. Sales outlets.

e. Consumer financing.

f. Product support. and

g. Additional technologies, products, and services.

B. Assess the kind of innovation that is needed.

1. Systematic.

2. Autonomous.

C. Assess the system as tightly or loosely coupled (regarding the parts that must be closely integrated with the new invention).

1. Tightly.

2. Loosely coupled.

The system-building organization needs to have a set of organizational capacities that are well-matched to the particular needs of the system-building endeavor. These include capacities to gather information about, and to exert some control over, and to coordinate each of the relevant parts. Likewise, capacities are needed for centralized planning and coordination. At the beginning of system-building effort, the capacities that are directly available to organization should be identified and evaluated, and determine if these are sufficient for above tasks, if additional in-house capacities need to acquired, or if they can be access through network relationship.

III. Assess: Determine the organizational capacities that will needed to

A. Integrate each invention with each important part of the sociotechnical system.

1. Routines for control.

2. Routines for coordinate.

3. Routines for gain information.

B. Centrally coordinate the overall system-building process

1. Routines for control,

2. Routines for coordinate,

3. Routines for gain information,

4. Routines for generate funding,

5. Routines for strategic planning, evaluation, and oversight,

IV. Assess: Determine to what extent each of the above is available

A. In-house

B. Must acquired or built in-house

C. Through a network

System-building efforts do typically require a significant, long-term investment of money before success can be achieved if ever. However, it can cost substantially less and have a greater chance of success if system building is started at a small scale and then slowly and efficiently ratchet up to a larger scale and degree of complexity. Pilot projects and studies are conducted in the early stages to identify and solve problems before expensive, full-scale infrastructure is built. System-building efforts should not be taken to the next stage until most or all of the major problems have been resolved according to objective, predetermined criteria.

V. Plan a multistage process pilot project and study to access and adjust the fit of the invention with the rest of the system using the above organizational capacities.

   A. Conduct system building in successive stages of scale and complexity and then ratchet up.

      1. Pilot project and study.

      2. Intermediate project and studies, as needed.

      3. Full-scale production and market testing.

   B. Within each stage, determine the order in which parts of the system need to adjusted, integrated, or built anew to ratchet up the size and complexity of new systems arrangements.

   C. The amount of time for each stage.

   D. Cost estimates for each stage.

   E. Evaluation criteria for assessing the fit between the invention and the rest of the system at each stage.

In most systems, organizational capacities for system building will be integrated together both by internal management hierarchies within organizations and by network relationships among organizations. While management hierarchies can be an exceptional source of capacities for information, control, and coordination, it is also typically very expensive and may not always be needed. Networks can sometimes suffice. The young organizations that typically engage in more radical, system-building efforts are usually capital-starved and thus tend to be reliant on network relationships to access many of the organizational capacities that they need for system building. However, the advantages of internalization vs. network relationships should be carefully weighed. There are situations where networks simply will not suffice for particular system-building endeavors. The most obvious of these is when particular capacities are not available through networks, and this is common when developing radical new inventions that require new systems arrangements and capacities—such as production facilities, consumer financing, sales outlets, and specialized R&D facilities—that are not otherwise available. Also, even if these arrangements and capacities do exist within the organization's network, the organization that has these capacities might not be willing to cooperate in a system-building effort, or if willing to cooperate the organization might not be developed enough to be a valuable participant in the network of system builders. In which case, it is often desirable if not necessary for an organization to internalize capacities into its management hierarchy.

VI. Rationalizing organizational capacities into hierarchies and networks.

A. Deciding which internal capacities are needed and where network relationships will suffice.

1. Internal capacities are needed for control and coordination when . . .

   a. The system is tightly coupled

   b. Inventions require systematic innovation

2. The use of networks relationships can suffice when

   a. The system is loosely coupled

   b. Inventions only need autonomous innovation

B. However, internalizing parts of a system always advantageous when organizations and individuals

1. Are not motivated to cooperate with system builders

2. Do not have the capacities to be an effective participant in a network with system builders

3. It is not possible, for whatever reason, to integrate capacities of the second organization with the capacities of the first organization.